No. L.

REPORT

TO

THE RIGHT HONOURABLE THE SECRETARY OF STATE FOR THE HOME DEPARTMENT

ON

The Circumstances attending three Explosions which occurred in Glasgow on the night of Saturday, 20th January, and the morning of Sunday, 21st January 1883.

BY

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H.M. CHIEF INSPECTOR OF EXPLOSIVES.

Presented to both Houses of Parliament by Command of Her Majesty.

SIR, Home Office, 14th March 1883.

I HAVE the honour to report that in obedience to your Order (Home Office, No. A 24407), made under the 66th section of the Explosives Act, 1875, I have held an Inquiry into the circumstances attending three explosions which occurred in Glasgow during the night of Saturday, 20th January, and in the early morning of Sunday, 21st January 1883.

The first of these explosions occurred at the Tradeston Gasworks of the Glasgow Corporation at about 10.10 p.m. on the 20th January; the second occurred about 12.30 a.m. on the 21st January on a bridge by which the Forth and Clyde Canal is conveyed across Possil Road; the third occurred at about 1.15 a.m. on the 21st January in a disused shed belonging to the Caledonian Railway Company, and situated near their Buchanan Street Station.

My connexion with these explosions arose from a telegram despatched by the Procurator Fiscal, Mr. W. Brown, with the approval of the Sheriff, requesting that I might be directed to proceed to Glasgow to assist in elucidating the explosions which appeared to be of a mysterious and suspicious character.

I took the earliest opportunity of proceeding to Glasgow, and the Procurator Fiscal had, at my request, caused the scenes of the explosion to be left as little undisturbed as possible pending my arrival.

I desire to take this opportunity of stating that I have received the most valuable assistance from the Procurator Fiscal, who has spared neither time nor pains to further the objects of my inquiry.

Statement of conclusions with regard to all three explosions.

It will be seen, as I have already stated in an *interim* report,* that I have arrived at a decided conclusion that all three explosions were effected by the agency of a nitro-compound and that they were wilfully effected by some evil disposed person or persons.

I have not felt that it entered within the scope of my duty to inquire into who these persons were likely to have been or by what motives they were impelled, that, as it appears to me, is strictly a duty for the police.

I will now proceed to state the circumstances attending each of the explosions, in the order in which they occurred.

I.—*Explosion at Tradeston Gasworks.*

First explosion (Tradeston Gasworks).

The first explosion occurred about 10.10 p.m. on Saturday night, 20th January, at the Tradeston Gasworks.

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* Dated 17th February 1883.

These works form one of the establishments in which the manufacture of gas is carried on by the Corporation of Glasgow for the lighting of the city, and are under the management of Mr. W. Foulis, C.E.

The main part of the works is situated on the north side of the Lilybank Road, but in 1870 a large gasholder was erected on the south side of this road, and it was in connexion with this gas holder that the accident now under notice occurred.

The situation of the holder and of its surroundings is shown on the accompanying plan (plate No. 1.) With the exception of this holder, and of a tank to the east adapted for another holder of the same size (not yet erected), and of the governor house to the north, and a cottage at the gate at the north-east occupied by a man in the employ of the Corporation, and a stable and outhouses near this cottage, there were no other buildings or works on this portion of the Corporation property, which is bounded on the north by Lilybank Road, on the east by a large foundry, on the south by waste ground extending to Maxwell Road, and on the west by Muirhouse Lane, beyond which about six small cottages will be observed on the plan distant about 90 feet from the holder.

There are some sheds and a rope walk extending along Muirhouse Lane, and between it and the cottages and to the north of the sheds and rope walk, and between them and Lilybank Road, a quantity of wood is stacked. Muirhouse Lane is separated from the ground on which the holder is situated by an open tarred wood paling; while the ground is bounded along Lilybank Road by a brick wall.

The gasholder is of very considerable dimensions. It consists of one outer and inner lift, each 30 feet high, and with an internal diameter (outer lift) of 160 feet. The capacity of the holder is 1,200,000 cubic feet; its working capacity 1,148,180 cubic feet. It was built by Messrs. Laidlaw and Son (Glasgow), gas engineers; and the plates of which it is composed are of the following dimensions. Top plates from $\frac{5}{8}$ths of an inch to No. 12 B.W.G. (= ·109 inch); side plates, inner lift, 12 B.W.G. (= ·109 inch), except the top and bottom row, of which the plates are $\frac{1}{4}$ inch thick, and except opposite to the pillars, where the plates are $\frac{1}{4}$ inch thick; outer lift, same as inner, except that the plates opposite to the pillars are $\frac{3}{16}$ths of an inch thick instead of $\frac{1}{4}$ inch.

Some of the principal details of the holder are shown in the accompanying plans (plates 2 and 3).

The holder worked in a tank sunk 30 feet below the level of the ground, and the junction of the inner and outer lifts was sealed when the inner lift was at its full height by an hydraulic cup-joint of a construction commonly employed in gasholders, and of which the details are shown in the plate No. 2. The details of the wrought iron brackets by which the top of the cup was attached to the wheel which worked in the guide plate of the pillar, up and down which the lifts worked, are given in plate No. 3.

There were 16 of these pillars run round the margin of the tank; they were of cast iron, 65 feet high and 3 feet diameter with a massive square cast iron base, which rested on a stout sandstone coping, which formed the upper edge of the tank.

The holder was in use on the night of the accident, and in conjunction with three holders on the north side of the Lilybank Road was supplying 26-candle gas to the whole of the south side of the city with a pressure of $2\frac{1}{2}$ inches.

The only servant of the Corporation on duty at this time near the holder was a man called John Gibson, whose duty it was to register and regulate the consumption of gas every hour, and for this purpose he visited the gasholder and governor at least once every hour, occasionally going as might be necessary to the outlet valve nearly opposite the governor house, or still more occasionally to the inlet valve on the north-west of the holder.

At 10.10 p.m. the inner lift was at a height of 22′ 6″ and contained 350,000 cubic feet of gas.

At this moment Gibson, who was in the governor house, was startled, and general alarm was created in the neighbourhood, by a violent explosion on the west side of the gasholder, followed by the inflammation of an immense body of gas issuing from the south-west side of the holder, *i.e.*, the side towards Muirhouse Lane. At the same moment there was a rattle of falling fragments and débris, of which a number fell in the neighbourhood of the governor house and beyond, and flame was observed to be issuing from numerous holes in the roof of the holder, which began to descend rapidly.

The man Gibson stood at the door of the governor house for a short space of time (estimated by him to have been about *two* minutes) and then ran to the gatehouse to alarm the man Harper, who lived there, and he looked round when he got near the gatehouse (which is 83 yards from the governor house) and remarked that the holder was quite down, and that although flame was still issuing it was with greatly diminished violence, from which circumstance he concluded that nearly the whole of the gas contained in the holder (about 350,000 cubic feet) had burnt out, and that what remained was burning under greatly diminished pressure[*] This was probably from three to five or six minutes from the time of the explosion.[†]

After alarming the man at the gatehouse Gibson with commendable promptitude and presence of mind went across Lilybank Road into the other part of the works to open the inlet valves of the holders there, and so to give relief to the gas which was being made, and he then returned to the injured holder and with some other men who accompanied him from the works proceeded to shut off the inflow of gas from the holder at the inlet valve; and they then shut the outlet valve. The vapour from the naptha in the holder continued to burn until 8 a.m. the following morning.

To return to the effects of the explosion, which it may be here stated was certainly heard for a distance of at least four or five miles,[‡] and is described as having been exceedingly sharp and well defined. One effect was to extinguish a number of lamps in the district supplied by these works.[§]

Breakage of windows.

Another effect was to break windows in some houses situated at a considerable distance from the works.[||]

Injury to houses behind Muirhouse Lane.

But the only houses very sensibly affected were the cottages behind Muirhouse Lane (distant 90 feet from the holder, and immediately opposite to the point where the explosion occurred).

I found that these houses all exhibited more or less of the sort of injury which is commonly produced in the neighbourhood of an explosion; that is to say, in addition to the breaking of the greater part of the windows, some doors were forced in, some plaster was shaken down, crockery was broken, pictures were thrown down, and the lighter objects in the houses generally upset. In addition, there was scorching of some of the woodwork and fences outside. But one or two points, which will be found to be important when I come to deal with the cause of this accident, call for special notice.

Thus, (1) there had evidently been nothing of the nature of an explosion *inside* the houses, all the effects had been produced from the outside; (2) there had evidently been nothing of the nature of a fire *inside* any of the houses, whatever burning was observable was strictly limited to the exterior; (3) the impulse of force had evidently proceeded towards and not from the houses. Nine of the occupants of these houses sustained injury from burns; and two sustained slight bruises from being knocked down by the shock, or by falling in their hurried attempts to escape.

I am quite unable to account for the burning of these persons if they were actually inside the houses during the whole occurrence. It is difficult to understand how, if persons in the houses could be so severely burnt as to necessitate their removal in some cases to the infirmary, the houses themselves should exhibit no traces whatever of burning in the interior; that which would scorch a human being would, I should be disposed to think, unfailingly scorch or affect many of the articles which these cottages contained,—at any rate the lighter and more inflammable articles, such as bed hangings, window curtains, &c.[¶]

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[*] The gas necessarily continued to flow in through the inlet pipe until Gibson subsequently closed it; but the holders being down the gas was no longer burning under pressure.

[†] It is impossible to ascertain this point exactly and it is not very important. Gibson thinks the time was about three minutes, but it is possible that it may have been a little longer. It could hardly have been less.

[‡] I have ascertained this by inquiry of several persons who lived at distances of from 3 to 5 miles and who were startled by the explosion.

[§] Mr. Foulis explains the non-extinction of all the lamps through the district as follows:—"Although the
" main supply for a portion of the district is from the damaged holder, yet there are connexions from the
" other holders which kept the lights burning although not to their full strength. The portions of the district
" supplied by the other holders were not affected. What happened was this:—When the rupture occurred
" in the holder the large escape of gas necessarily very much reduced the pressure in the mains, and it would
" remain reduced until the valves of the holder were shut. This reduction was naturally most felt at the low
" levels of the district, and there, but in some cases only, the gas went out. When the valves of the holder
" were shut the pressure in the mains increased, and the whole district was supplied from the other holders,
" although the supply was not quite so full as before, there was very little inconvenience to the public. In
" places where the gas went out it was not for more than five or six minutes. . . . . . . Not many of
" the public lamps went out."

[||] I have no definite information as to the distance at which windows were broken. Some of the newspaper accounts say that some houses up to the radius of a mile were "affected," and it is certain that several windows were broken in parts of St. Andrew's Road and Kenmure Street, distant about 300 yards to a quarter of a mile.

[¶] In one house a hanging paraffin lamp was thrown down and broken, but apparently even the highly inflammable spilt oil had not been ignited although six persons are stated to have been burnt in this room.

In the course of my inquiry it was admitted to me that in one or two instances, at anyrate, the persons who were burnt had run out of the doors on hearing the explosion, and in these cases the explanation is simple. They had simply met the rush of flame or hot blast caused by the ignited gas issuing in immense volume from the side of the gasholder facing the cottages and so had become burnt.

And a statement which was made to me by another of the injured men perhaps suggests an explanation in the other cases. He at first said very positively that he was in the house when he was burnt, but he at last admitted that he really did not know what he was about, or whether in his excitement and terror he ran out of the house or not. All the people were naturally in a state of great and sudden alarm, and would be more likely, I should say, instinctively to rush to the door to escape than to remain quietly inside a cottage which must at the moment, owing to the blowing open of doors, breaking of windows, falling of crockery and pictures, and general wreckage, have seemed as if it was rattling down about their ears.

And of course directly they went to the doors they would find themselves met by a scorching blast and flame, and be immediately driven back.

Injury to sheds between cottages and Muirhouse Lane.

Proceeding from the cottages towards the gasholder, the light wooden sheds which compose the stable, hen roosts, and out-buildings generally, had sustained exceedingly little injury. It was evident that no explosion had occurred within these sheds, and the fire seemed to have passed over the top of them. At any rate, as in the case of the houses, it had been scarcely sensible, if at all, in the interior; and the hens and chickens and pigs which were kept in some of them were uninjured.

But outside these sheds, as in the yards about the houses, woodwork had been burnt, a quantity of clothes hanging on a line had been consumed, a cat had been burnt to death, and there was generally an appearance as of an intense heat having been operative for a short space of time.

Injury to wood stack.

The wood stack had been slightly charred, but does not appear to have been actually set fire to.

Injury to fence.

Muirhouse Lane, as already stated, is separated from the Corporation property by an open tarred wood fence or paling running the whole length of the lane. Altogether about 30 yards of this fence is burnt or charred. The whole of this length is burnt on the side next to the holder; a portion of the other side only is burnt, but it is noticeable that whereas all the timbers towards the holder are more or less burnt, some very severely, the posts and heavy timbers are scarcely burnt at all on the side away from the holder, and the effects on this side appear to have been mainly limited to those lighter rails which having caught fire (presumably in the first instance on the side towards the gasholder), had blazed up, so as to present an appearance of having been burnt all over.

Projected débris between holder and fence.

Crossing the fence and proceeding towards the holder, the evidence of a sharp explosion accumulates, in the shape of a large number of fragments of iron which have been projected by the explosion.

There were 39 fragments recovered between the holder and the fence, and a few pieces had been blown over the fence. Of these 39 fragments, at least 28 were identified as portions of the bracket or as parts of the bolts, pulleys, or connexions of the bracket of the outer lift. And three pieces removed from the other side of the fence also belonged to the bracket.

Some of the pieces of bracket were deeply pitted on one side, a point which will hereafter invite special observation.

There were also recovered between the holder and the paling two pieces of tape to which I shall have to advert more particularly hereafter.

The positions of the various pieces of débris, which I caused to be carefully noted before removal, are shown on the plan (*see* plate No. 4), and the descriptions and identification of the several pieces (numbered to correspond with the plan) are given in Appendix A.

I shall have occasion hereafter to recur to these fragments. For the present it will be sufficient to remark that of the 39 pieces found between the holder and the fence, 34 lay to the left (or north) of the pillar at which the explosion occurred, and the three pieces on the wood stacks also lay in the same direction.

On the other hand, the five pieces to the right (or south) of the pillar, were none of them pieces of or immediately connected with this bracket.

It was thus evident that the explosion had operated to the right of the bracket.

Injury to pillar.

The pillar where the explosion occurred had its base seriously cracked (*see* photographs Nos. 2, 4, 5,*), and on the side towards the holder and immediately to the right

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* It has not been thought necessary to reproduce the photographs for the purposes of the printed report.

(or south) of the position which the bracket had occupied, there was noticeable a distinct circular indentation from 3″ to 4″ in diameter, as if the metal had sustained a violent blow on this spot, and the whole of the face of the pillar base on the right of the bracket was deeply marked and pitted (*see* photographs Nos. 4 and 5).* An ornamental plate at the back of the pillar was cracked and a piece broken off (photograph No. 3).* The stone coping below the pillar was similarly marked (photographs Nos. 4 and 5.)*

Injury to guide plate.

About 8 feet of the guide plate had been broken off the pillar, and was subsequently recovered between the outer holder and the walls of the tank to the left of the injured pillar. The lower part of this guide plate exhibited on the right outer and right inner sides the same pitting which has been remarked upon in the case of the pieces of bracket and the base of the pillar. The left cheek of the bracket, with connecting bolts, was found between the lift and the walls of the tank near the broken piece of guide plate, whole and practically uninjured, except that the right end of the bolt had been broken off.

Injury to chain.

The chain which supported the outer lift at this pillar had been snapped in two and had (doubtless on its sudden release from the severe strain momentarily put upon it) whipped itself round the girder at the top of the pillar.

When I first visited the scene of the explosion the water had not been removed from the tank. I was therefore unable to examine the interior of the holder, or to note accurately the amount of damage which it had sustained.

Injury to cup joint (observed from exterior).

Injury to holder (observed from exterior).

It was however possible to note that the plates composing the cup joint opposite to the injured pillar were smashed, evidently from a force operating from above them, while the side of the holder in the neighbourhood of the pillar had a large rent in it partly the result of the explosion, but principally the consequences of the plates which had been started by the explosion becoming rucked up and torn against the top of the outer lift during the rapid fall of the top lift.

It will be convenient to reserve a fuller description of the injury done to this portion of the holder until I deal with the state of things observed in the interior after the water had been pumped out of the tank.

Condition of top of holder.

Passing to the holder as I found it on the occasion of my first visit (when things remained exactly as they were after the explosion) the point of prominent interest consisted in a large number of holes and bulges in the top of the holder. There were 16 complete and more or less ragged perforations of the holder, varying in dimensions from 1½″ × ¾″ to 22″ × 7″ in size. There were 16 bulges, of which four were accompanied by cracking of the plate† (*see* Plate No. 1 and Appendix A.).

But there was this noticeable feature about the holes, bulges, and cracks, that they had all been effected from the interior; that is to say, the edges of the holes were turned outwards, and the bulges and cracks were upwards.

It is also important to observe that the holes and bulges radiated with remarkable fan-like symmetry from the injured pillar as a centre.

Projected débris beyond the holder.

Beyond the holder and following roughly the same lines and general limits of dispersion, a number of fragments were picked up, while many had been removed before their position could be noted.

But the position of 15 fragments is noted on the plan (*see* plate No. I), and four of these were between the holder and the wall which bounds Lilybank Road, and the remaining nine were beyond Lilybank Road, about the gasworks and on the Caledonian Railway which runs parallel to Lilybank Road and between it and the north part of the gasworks.

Among the pieces found on the railway (distant about 160 yards from the injured pillar) was a small portion of ¼″ plate, which exhibited in a very remarkable degree the peculiar pitted appearance which I have before noted as characteristic of some of the other fragments. It may be at once stated that this piece (No. 2 on plan, *see* plate No. 1) and six other fragments found to the north of Lilybank Road were undoubtedly fragments of the side plate of the holder opposite the point of explosion, and as they lay at distances varying from about 150 to 200 yards from the injured pillar (*see* plate No. I) it follows that they must have been projected these distances by the explosion.

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* It has not been thought necessary to reproduce these photographs for the purposes of the printed report.

† These figures do not represent the full measure of the effect, for when the roof plates were removed it was found that the framing had been struck very frequently, and in one instance an angle iron bar near the side furthest from the explosion and ⅜″ thick had a hole about 1″ diameter punched clean through, almost as if it had been done by a machine.

Condition of interior of holder.

After the water had been pumped out of the tank, I revisited Glasgow, and attentively examined the interior of the holder with the following results.

Injury to cup joint (observed from interior).

Between the holder and the sides of the tank, and immediately under the cracked pillar we recovered the fragments of the cup joints which, as before stated, had evidently been destroyed by a force operating from above (*see* photograph No. 4); and the force had been of such a character that the plates, rivets, &c. composing the joint had been blown into a number of very small pieces, the character of which may be inferred from the fact that 52 of these pieces weighed together only 21 lbs.

There were also found in the lute two larger pieces of plate.

Débris on floor of tank.

Scattered about the floor of the tank were 19 pieces of débris, consisting of the half round iron stiffener which had been at the back of the side plate of the holder opposite to the injured pillar, and which lay in two pieces, to the left point of this pillar, as shown on the plan, and of pieces of plate, nuts, and washers which had formed portions of the shattered side of the holder, and were distributed in directions corresponding generally very well with the general fan-like distribution of the holes and bulges on the top of the holder (*see* plate 4, and compare with plate 1).

Injury to holder (observed from interior).

The upper part of the side of the top (or inner) lift next to the cracked pillar had in it a large chasm measuring 18′ high × 24′ wide.*

Below this the next plate (being the 12th from the top of the holder) had in great part disappeared, while a portion not actually blown away had been violently doubled back into the holder, the edge of this doubled back portion being pitted on its outer side in the same way as some of the recovered débris. Below this plate, the three remaining plates of which the top (or inner) lift is composed, were split vertically down the line of rivets and blown inwards.

It will be observed that as the lift was 22′ 6″ high at the moment of the explosion, and as each plate is 2′ high, the 12th plate from the top would be exactly opposite to the top of the cup at the moment of explosion.

Perforation of sides of holder.

The lift, examined internally, consists in all of 32 panels or compartments, each 16′ in length. Of these the two compartments immediately underneath the cracked column are injured as above described, but excluding these, we find that 9 compartments on the right and 11 compartments on the left are wholly uninjured. But in the 10 remaining compartments, *i.e.*, those which occupy the opposite side of the holder to that on which the explosion occurred, there are no less than 77 complete perforations, some ragged, but some very clean cut, and all evidently effected from the interior (*see* photograph No. 7, which might almost be taken for a representation of a row of Shoeburyness targets after being exposed to a fire of shrapnel shell or case†).

The number of holes in the different compartments were as follows:—

		Holes.
In 13th compartment to left of injured pillar		4
„ 14th	Ditto	6
„ 15th	Ditto	9
„ 16th	Ditto	24
„ 17th	Ditto	16
„ 18th	Ditto	5
„ 19th	Ditto	6
„ 20th	Ditto	3
„ 21st	Ditto	1
„ 22nd	Ditto	3
	Total	77

Observations in connexion with perforations in side of holder.

There are certain points in connexion with the distribution of the holes which invite observation.

In the first place, assuming the point of explosion to have been immediately in front of the cracked pillar and to the right of the bracket, this would be exactly opposite to the junction of the 16th and 17th compartments (counting from the left). And as a matter of fact we find that these two compartments contain respectively 24 and 16 holes, or more than half the total number of holes in the whole 10 compartments perforated with débris.

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* The greater portion of the plate from this chasm was unquestionably not blown off, but ripped off against the sides of the cup as the inner lift fell. (Photographs Nos. 1, 2, 3.)

† It has not been thought necessary to reproduce the photographs for the purposes of the printed report.

In the second place, excluding these two central portions we find that there are 19 perforations to the left of them, and 18 perforations to the right of them, thus exhibiting remarkable equality of effect.

In the third place, however, we find that whereas the 19 perforations on the left are disposed in 3 compartments (or more correctly in 2½ compartments, for there were no perforations beyond the left centre of the 13th compartment), the 18 perforations on the right were distributed over 5 compartments. In other words, excluding the two central compartments, the 19 holes on the left were distributed over a space of 40 feet, and the 18 holes on the right over a space of 80 feet, thus showing a very much greater tendency to *scatter* on the right than on the left,—a point which I shall presently show admits of a satisfactory explanation.

In the fourth place, it is worthy of remark that while there was in no case any perforation below the level of the 12th plate from the top, that having been the plate opposite to which the explosion occurred, there were several perforations in that row of plates, whence we derive some measure of the great velocity with which the fragments, many of them exceedingly small and light, were projected, since they were no doubt projected across the holder (a distance of 160 feet) before the latter had fallen any sensible distance. In fact, they must have traversed the holder with very great velocity indeed, for rapidly as the holder fell this row of plates had obviously not time to descend below the surface of the water which was opposite to it at the moment of explosion, before these fragments reached and perforated the opposite side.

Lastly, the line of dispersion of the fragments corresponds very accurately with the general distribution of the fragments in the top of the holder and on the floor of the tank.

In addition to the perforations of the plates, many pieces of débris had evidently impinged upon them and upon the central column with considerable force. And one of these pieces which proved to be a small rivet head, deeply pitted, had been thrown with such velocity that it had penetrated into the plate of one of the central compartments and remained fixed there, a source of some bewilderment at first to those who discovered it, and who could not understand why a rivet should appear in the centre of a plate, such being the aspect which it at first presented.

I believe I have now specified with sufficient accuracy all the more noteworthy effects produced by the explosion.

Examination of question. How did the explosion occur? Subject resolves into two branches.

I have next to consider in what way this explosion occurred, and this part of the subject resolves itself into two separate branches.

A. Was it what is properly called an "explosion of gas," viz., an explosion of a mixture of gas and air?

B. If not, to what agency can the explosion be referred?

I think it will be found that the circumstances of the case are such as to enable a perfectly complete and confident answer to be given to these questions.

A. Examination of question whether explosion was due to gas.

A.—Was the explosion one of gas (and air)?

(1.) Explosion external to gasholder.

(1.) *It is quite certain that the explosion, however occasioned, was external to the gasholder.* The proofs on this point appear to me to be absolutely conclusive.

(*a.*) The whole of the effects produced have radiated from a centre which is external to the holder. Thus we find that the pieces of bracket and the broken pieces of guide plate are all blown to the left, the pieces of the cup joint are blown downwards, the pieces of the holder itself are all blown forward in a cone of dispersion of which the apex is immediately to the right of the bucket.

(*b.*) The whole of the effects upon the side of the holder near the point of explosion have evidently been from without, as is exemplified by the blowing *in* of the plates (*see* rent at junction of three lower plates in photograph No. 6),* by the violent doubling *inwards* of a portion of the 12th plate (*ibid*), and the blowing *inwards* of the remainder, by the distribution of what may be distinguished as the holder débris in a symmetrical forward cone, and by the character and direction of the holes and bulges in the holder, which have all been made from within and in no single instance from without.†

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* It has not been thought necessary to reproduce the photographs for the purposes of the printed report.

† The circumstance that the explosion can be shown to have been from without renders it really unnecessary for me to examine the question of the possible destruction of a holder by what would be commonly called a gas explosion within.

But there is so much popular misapprehension on this point that it may be worth while to offer a few words on the subject.

It is, I believe, not uncommonly supposed that a holder is a large reservoir or magazine of highly explosive matter. Nothing can be further removed from the fact. A gasholder under normal conditions contains nothing explosive whatever, and therefore could not possibly be exploded under these conditions. Coal gas

Particular spot where explosion occurred.

(2.) *It admits, I consider, of no dispute that the explosive force operated from a point immediately in front of the cracked pillar close to the right of the bracket and just over the cup joint.*

This is shown (*a*) by the injury inflicted upon the front of the pillar, which, as already stated, is cracked and pitted, and bears marks as of a powerful blow inflicted upon it; (*b*) by the absence of any appreciable injury on any other part of the pillar; (*c*) by the fact that the whole of the right cheek of the bracket was broken up into small pieces and projected to the lift; (*d*) by the absence of injury to the left cheek of the bracket; (*e*) by the destruction of the cup joint, and the blowing of the same downwards in a number of small fragments; (*f*) by the blowing into small pieces and the projection inwards of a great part of that particular plate of the holder which at the moment of explosion is known (from the then elevation of the lift), to have been immediately opposite to the right bracket.

Explosion did not occur in any enclosed space but in the open air.

(3.) *It follows from the two preceding propositions that the explosive force was developed not within any enclosed space or chamber but in the open air.*

If, as I submit is incontestable, the explosion occurred between the pillar and the holder, and above the cup joint, it is really unnecessary to demonstrate that it could not have resulted from the formation of an explosive gas mixture within either of the only two enclosed spaces or chambers which exist external to the holder, and in its immediate vicinity, viz.: the hollow base of the pillar and the annular space (about 3″ deep), within the cup joint, and immediately above the water. But in order to dispose of any possible doubt on this point it may be well to state that independent considerations make it quite certain that the explosion could not have originated within either of these enclosed spaces. Not only have we the substantial and really conclusive evidence which is afforded by the fact that the injuries which the pillar and cup had sustained were obviously derived from an explosion on the outside (the nature of the cracks, the circular depression on the outside of the face of the pillar, the deep pitting on the same face, and the breaking in and projecting downwards of the plates of the cup alike prove this), but we have in the case of the pillar the further considerations,—

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by itself is not explosive, it is not even inflammable. It is capable of forming an ingredient of an explosive mixture, just as charcoal when mixed with certain other ingredients will form gunpowder. But coal gas can no more explode without a very large admixture of oxygen, supplied artificially or derived from the air or other source, than can charcoal explode without an admixture of some body containing oxygen (such as saltpetre). The late Dr. Arnott said on this point that coal gas "like the charcoal of gunpowder is only one "of the elements of a fulminating mass, and can no more explode than the contents of a coal cellar can. "Before it can burn at all every particle or measure of it must find somewhere, and mix properly with, two "particles or measures of oxygen gas. A lighted taper plunged into mere coal gas, instead of exploding the "gas, is itself instantly extinguished by it." (Arnott on the Smokeless Fire, &c., p. 212.)

The proportion of air requisite to form an explosive mixture varies with the character of the gas. With the 26-candle gas supplied at Glasgow, the most powerful explosive mixture is one in which 12 parts (by volume) of gas are present in 100 parts (by volume) of gas and air (=about 1 of gas to 8 air); with the 16 candle gas supplied in London, the most powerful mixture would consist of about 16 parts of gas in 100 parts of gas and air (=about 1 gas to 6 of air). And on either side of this maximum explosive mixture there is in each case a zone, so to speak, of gradually diminishing explosiveness, until we reach on the one hand the limit at which there is an excess of air, and on the other the limit at which there is an excess of gas. According to Mr. Foulis, the zone in the case of the Glasgow gas would be limited in the one direction by an admixture of about 8 parts of gas in 100 parts of gas and air (=about 1 gas to 11½ air), and in the other direction by an admixture of about 16 parts of gas in 100 parts of gas and air (=about 1 gas to 6 air). Beyond either of these limits no explosion is possible. Consequently a gasholder in a normal condition, *i.e.*, filled with gas and sealed by water below, contains nothing which can explode; and it is, I believe, a fact that at the sieges of Paris and Strasbourg shells struck and exploded within gasholders without exploding or even firing the gas, as indeed it would be physically impossible for them to do. Consequently popular apprehensions as to the possible explosion of gasholders are wholly baseless.

Of course peculiar conditions may exist under which the contents or a part of the contents of a gasholder might be exploded, but this would only be when from some cause or other air had become mixed in effective proportion with the gas. Such conditions are extremely difficult to produce, and consequently any accident of this sort is extremely rare, but they might conceivably arise and perhaps have arisen from the tilting and unsealing and partial destruction of a holder in its descent, whereby gas could escape and air enter; or if a holder became "hung up" and unsealed, possibly in time a more or less explosive mixture might be formed in the interior. An empty holder is really, though the statement may seem paradoxical, more dangerous than a full one, for the vapours which are constantly given off in such a holder from the naptha floating on the water are capable of combining with air in dangerous proportions, and I am given to understand that an explosion occurred at Preston some years ago from the falling of a red hot rivet into an empty holder which was being repaired and in which an explosive mixture had accumulated in this way.

But it may be emphatically stated that a gasholder in normal condition and working order could be no more exploded than a tank full of water could be exploded, and the gas which it contains could not even be ignited until it issued from the holder and had combined with the requisite proportion of atmospheric air.

This subject was examined very clearly and usefully by Captain Shaw, C.B., Chief Officer of the Metropolitan Fire Brigade in 1867, at a time when there existed some apprehension of Fenian outrages in connexion with the possible "explosion" of gasworks.

First. That the column would be wholly unfavourable to such formation, because (*a*) it has no opening through which gas could enter except an ornamental grating on the side away from the holder; and (*b*) as there is a free communication about 3 feet in diameter right up to the top of the pillar, any gas which might have got inside would at once rise through the column. In fact, the base of the pillar is strictly not an enclosed space at all, but a space enclosed on four sides and open at the top. and therefore specially favourable to the escape of any gas which might accidentally have got into it.

Secondly. If we assume that the explosion could have originated within the pillar base, this would still leave wholly unexplained the fracture of the bracket, guide plate, cup and holder plates.

In the case of the cup, we have in addition to the considerations indicated above, these further ones:—

First. That although the annular space in question might have contained gas, it is difficult to conceive how it could also have contained air, without the presence of a large proportion of which an explosive mixture would not exist;[*] and

Secondly. Even if we could assume the possible presence within this annular space of an explosive mixture, such mixture could certainly not have been locally present in sufficient quantity, or had a sufficient force to have demolished the very strong plates which formed the top of the joint; and

Thirdly. If a powerfully explosive gas mixture could possibly have been present it would not have found expression on the strong plates, but would have relieved itself by acting downwards through the water and bulging or breaking some of the comparatively weak side plates.

Some apology is indeed needed for devoting space to an examination of a branch of the subject which really admits of no serious discussion.

Explosion was not an explosion of gas.

(4.) *It is certain that the explosion was not a gas explosion at all,* i.e., *was not an explosion of a mixture of gas and air.*

It would, I believe, be safe to rely upon the three foregoing propositions as furnishing conclusive proof that the explosion could not have been due to a leakage of gas and to the consequent formation of an explosive gas mixture. For I have failed, after diligent search and personal inquiry of gas engineers and chemists qualified to express an opinion on the point, to discover any evidence as to the possibility of a violent gas explosion occurring in the open air.

That it is possible for a body of gas issuing from a holder and coming into contact with flame to ignite with a certain energetic abruptness accompanied by some local commotion or disturbance, the whole realising an effect which in loose parlance may perhaps be described as "explosive," is not disputed. Such a case appears to have occurred at the Keighley Gasworks as recently as the 26th January last, and I am indebted to Mr. Laycock, the engineer of these works, for some particulars of this occurrence, in which what is called the "explosion" is said to have taken place in the open, but an explosion which inflicted absolutely no injury.

Circumstances attending gas "explosion" at Keighley.

The circumstances appear to have been as follows:—A high wind is stated to have caused the top lift of the holder to tilt or become unsealed in its descent, causing a leak, and the escaping gas entered an office 15 yards distant where there was a light and where it became fired, doing little damage in the office, but, running back towards the holder, it caused on the outside what is described as an "explosion," but one of so inconsiderable a character that as a matter of fact no harm whatever was done, and as Mr. Laycock says, "The gasholder is not injured in the slightest degree, and excepting the paint being blistered and burnt it would be impossible to tell that anything had occurred. . . . . . The holder was never stopped working and has not been stopped since."[*]

The formation in this instance of an explosive gas mixture external to any building is, I think, accounted for by the fact that the building in which the office is situated formed a re-entering angle opposite the holder, and the high wind sweeping past established a series of eddies in this angle, into which the escaping gas was thus being continually brought and mixed with air, and when the flash passed back from the office this mixture was fired under conditions of a sort of semi-confinement.

But not only do I believe that it would be contrary to all experience, but in my judgment it would also be absolutely outside the bounds of physical possibility for a gas mixture ignited in the open air to develop an energy which would shatter masses of cast iron into many pieces, crack and deeply indent and pit a massive cast iron column, deface a stone coping, break up the substantial wrought iron plates of an hydraulic joint into small fragments, and destroy a $\frac{1}{4}''$ wrought iron plate and project the fragments clean through the opposite sides and the top of the holder and some 100 to 150 yards beyond, besides attracting attention by the noise at a distance of some 4 or 5 miles.

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[*] *See* page 8, footnote, as to what this proportion would have to be.

[*] Letter from Mr. Laycock 14th February 1883; *see also* the "Review of Gas and Water Engineering," 2nd February 1883.

Indeed, the Keighley accident appears to furnish as satisfactory a practical reply to any suggestions as to the possibility of remotely approximating to these effects by the explosion of an unconfined gas mixture as could well be desired. For we have here an open air gas explosion occurring under conditions probably as favourable to the development of destructive energy as could have been suggested if the object had been to test the point experimentally. The mixture was accumulated under exceptional conditions and fired in the semi-enclosed space formed by the re-entering angle of a building, nevertheless neither the building in contact with which the "explosion" occurred, nor the gasholders at a few yards distant, nor any object or thing in the vicinity, sustained the slightest damage.

Again, if any material effects could be produced by an open air gas explosion those effects would necessarily bear some relation in general character to the effects produced by a gas explosion within an enclosed space. They would not be more energetic, more violently destructive, more intensely local than would be the effects of an explosion produced within, let us say, a gasholder itself. But experience goes to show that a gas explosion is comparatively slow and therefore distributed in its action. It does not tend to break up iron plates into fragments, but rather to bulge or upheave or rip them open. The character of its action is such that it has time to find out and operate along the line of least resistance. It is not, as is the case of an explosion of gunpowder or dynamite, the more or less instantaneous change of a solid occupying a small space into an immense body of intensely heated and correspondingly expanded gaseous matter, but the comparatively gradual expansion of a body already in a gaseous condition. In proportion to the suddenness or degree of the transformation will be the exhibition of local energy. Thus, dynamite when properly detonated is so much more rapid and energetic than gunpowder that it is unnecessary to confine it in order to develop its effects. The explosion is so quick that there is no time for it to seek the vent afforded by a line of least resistance. The surrounding atmosphere itself furnishes a very effective sort of tamping, and the popular fallacy that dynamite always and only "acts downwards" is merely a product of the observation that, unlike explosives of slower and less energetic action, it accomplishes an equal shattering effect in all directions, thus acting more vigorously in a downward direction than do those explosives which have time to develop their action along a line of least resistance.

And just as gunpowder is non-local as compared with dynamite, so gas effects are slow and distributed as compared with those of gunpowder.

Thus, if a tin cylinder be filled with the most explosive gas mixture and the end be closed by a lid or cap, and if this mixture be then exploded, the result in every case that I have witnessed the experiment has been simply to blow off the cap with a sort of dull puff. If gunpowder were employed the cylinder itself would be burst; while with dynamite it would be blown into small fragments. But with gas, even if the lid were soldered on, the effect would probably not proceed further than the expanding and ripping open of the cylinder; and it is a noticeable feature of this experiment that the explosion of the gas mixture as compared with gunpowder, and still more as compared with dynamite, was in all cases what may be characterised as leisurely and prolonged.

The results of the inquiries which I have instituted as to the general character of the effects produced by gas explosions correspond exactly with those of the above-named experiment, and with what on theoretical grounds might be anticipated.

But there fortunately exists some direct evidence as to the character of these effects in the shape of some wrought iron tanks which formed the subject of a series of recent experiments by the Admiralty Committee on explosions of gas in coal bunkers, &c.*

These tanks, of which two were 6′ × 4′ × 4′, and two were 4′ × 4′ × 2′, were composed mainly of $\frac{3}{16}$ inches riveted wrought iron plates. They were fitted with gas mixtures of maximum explosive power, and the mixtures were fired. The result, as described in the Committee's Report, is quoted in Appendix B, and is shown in the accompanying drawings (*see* plates 5 and 6).† It will be seen that these effects were what may be best described as distributed effects. There was bulging, tearing and ripping of the plates, and breaking and bending of stays, but nothing which in any way compared with the effects which I have described as having been produced at Glasgow, and which effects, as I shall presently conclusively show, were characteristic of a wholly different explosive agent.

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* This Committee was appointed to consider the question in consequence of the evidence given at the court martial on the loss of H.M.S. "Doterel."

The report is dated 14th March 1883.

† These plates have been reproduced by permission of the Lords Commissioners of the Admiralty.

Had an open air gas explosion occurred it is certain that the effects would have *less* (not *more*) closely approached those produced at Glasgow than when the effects, as in these cases, were produced by a gas mixture exploded under confinement.

But the considerations relative to this important branch of the subject admit of, and perhaps call for, further expansion.

Considera-tion of question of whether there was a leak of gas.

Thus, it would be necessary before any explosive gas mixture could be formed external to the holder that there should be some leakage of gas. I have accordingly directed particular attention to this point. I was made aware of an impression on the part of the occupants of the cottages behind Muirhouse Lane, that for some weeks previous to the explosion there had been an exceptionally strong smell of gas, which they attributed to a leak.* But of course the leak would have to be very considerable indeed to produce a powerful gas mixture external to the holder. Fortunately the question as to whether any such considerable leak had existed admits of what I must regard as conclusive solution from the returns kept at the works.

The amount of gas delivered from the Tradeston Gasworks is recorded every hour, and of course if a considerable leak became established the effect would be at once sensible in a largely augmented consumption of gas.

I have obtained a return of the deliveries of gas from these works† for each hour from 6 p.m. to midnight on the Saturday of the explosion and on each of the seven preceding Saturdays. This return is given in Appendix C. It will be observed that during this period the deliveries (allowing for the somewhat increased consumption which, I am informed, generally occurs for a few weeks before and after Christmas) were remarkably regular and uniform; while it is further noticeable that on the evening of the explosion the deliveries (except during the hour 10 to 11 p.m., when the gas lost by the destruction of the holder of course appears on the return) were less than on any of the preceding Saturdays to which this return relates.

These figures are corroborated by, and in their turn corroborate, the statement of the man Gibson before referred to, that the condition of the holder up to the time of the accident was satisfactory as regards leakage. He states most positively that before the explosion there was no unusual smell of gas. He had been up to the inlet valve at 9 p.m. that evening, and detected nothing unusual. And he asserts, in disproof of the existence of an appreciable leakage, that even during the day, when the inlet valve was closed, he has never known this holder sink more than about 2" or 3". No doubt Gibson's evidence is to a great extent that of an interested witness, as indeed in a sense is the evidence of all the officials connected with the gasworks, but it would be ungracious and unfair did I not at once add, as I desire to do most unreservedly, that I believe the evidence of these officials, so far as I have collected it, to be thoroughly reliable. And of course the books wherein the foregoing figures are recorded, and whence this return is derived, must be accepted as affording perfectly satisfactory testimony on this point; which also invites the further passing observation that it is to the interest of the engineers and officers of the works to prevent any escape of gas, so as to avoid the loss which such an escape would entail.‡

Other diffi-culties in way of ex-plaining occurrence by existence of a leak

But even if there had been an escape, some further difficulties of a formidable character would have to be encountered in any attempt to connect therewith the explosion of the 20th January.

As to ignition of escaping.

For example, supposing a leak of a formidable character to have disclosed itself, how could the escaping gas have become ignited? Muirhouse Lane was not lit in any way; the governor house of the works was the other side of the gasholder; the gate-house was still further off; there were no other lights or fires on the works. The gas assuming that a leak had become established.

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* I failed to discover that any representation had been made to the Corporation or to their officers on this point previous to the explosion.

† The return includes the deliveries from all the four gasholders in the Tradeston Works. The holder where the accident occurred was one of those at work all this period.

‡ It is certain that no sudden leak could have resulted from such a cause as that which existed at Keighley, for it was a perfectly still night, the holder was working quite smoothly and regularly and the fact that after the accident it descended with great rapidity but with perfect accuracy to the bottom of the tank, is sufficient and conclusive proof that the holder had in no way become disarranged or defective in its guides or bearings so as its descent would be likely to be impeded or misdirected.

nearest point at which the gas could have become ignited was at the cottages behind Muirhouse Lane, distant about 30 yards.

Assuming the gas to have travelled to these houses, and there become ignited, it is evident that the outhouses, henroosts, stables, and sheds, between the houses and the gasholder, indeed, the whole intervening space, must have first become charged with large quantities of gas mixed, we may reasonably assume, in approximately explosive proportions with the air. Accordingly, it would follow that when the gas fired at the houses, sensible effects of burning, and even perhaps something approaching an explosive effect, would have been exhibited in these sheds and out-houses and the intervening space.[*] But it has already been stated that the out-buildings generally had sustained exceedingly little injury. It was evident that no explosion had occurred within these sheds, and the fire seemed to have passed over the top of them. At any rate, as in the case of the houses it had been scarcely sensible, if at all, in the interior, and the hens and chickens and pigs, which were kept in some of them, were uninjured.[†]

In the second place, it is reasonable to believe that if a powerful gas mixture had ignited inside the houses they would have exhibited some symptoms of an internal explosion, or at any rate, of energetic burning. But I have already remarked that there were no effects whatever of either character discoverable within the houses.[‡]

Thirdly, if the gas had fired at the houses, the flash would have travelled back towards the gasholder, and the impulse of whatever force might have become established would unquestionably have been from the houses towards the gasholder. But, as already stated, precisely the contrary was the case. "The impulse of force had evidently proceeded towards and not from the houses;"[§] while it is further noticeable, in this connexion, that the burning of the paling between the gasholder and Muirhouse Lane was mainly on the side of the fence facing the gasholder, which, if a powerful body of ignited gas had proceeded from the cottages, is unlikely to have been the case.

In short, the whole character and direction of the effects appear to me to be absolutely inconsistent with and contradictory of the theory that gas escaping from the holder had been ignited at the cottages.

Even if a leak had existed is it certain that such leak would have produced any explosion whatever?

One other question remains which it may be worth while to consider. Assuming that contrary to what I believe to be plain proof, an escape of gas did occur, and that such escaping gas became ignited at the cottages, would such ignition have unnecessarily brought about an explosion at all?

To a great extent the question is already answered, so far as this particular case is concerned, by my arguments as to the impossibility of a formidably explosive gas mixture being formed in the open air, and by the evidence of the Keighley accident and other considerations which I have adduced to prove that even if we grant the establishment of something approaching an open air gas explosion, the effects could not possibly resemble even remotely those produced on this occasion.

But it may be well to add a few words to remove finally what I believe to be a not uncommon impression, that if an escape of gas occurs from a holder, and the gas becomes ignited there is great danger, not to say certainty, of some sort of explosion occurring.

It happens that we have actual practical experience which is conclusive on this point, and shows quite clearly that even with an ignited escape of immense proportions, an *explosion* need not be apprehended.

Probably the most striking example is furnished by what occurred at Nine Elms in October 1865. The circumstances are thus described by Captain Shaw, C.B. "A "dangerous mixture was carelessly or accidentally formed in the testing house, which "stood between the two large holders, and on the application of a light it exploded "with great violence, blowing the testing house itself into the air, doing immense "injury to the whole neighbourhood for about half a mile in every direction, and "smashing in the metal of the two great holders, thereby allowing the gas to escape "freely. One of the holders simply emptied itself into the open air, and its contents "passed off with no worse effect than making a strong smell. The other, which had "a rupture or opening of about 25 square feet, took fire from the retort house and "burned away with a great blaze and strong heat, but no explosion, and though I had "a strong force of steam fire-engines present it was not necessary to take any steps "beyond merely watching until the gas had been almost consumed, and then cooling

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[*] Any ignition of an explosive gas mixture within these sheds would have occurred under conditions of confinement which would have been favourable to the development of some moderate explosive effects.

[†] *See* page 4.

[‡] *See* page 3.

[§] *See* page 3.

"the holder with water, after which there was no difficulty in extinguishing the flame. "*In this case there was a combination of everything which is commonly supposed to cause an explosion, but the gas burned away notwithstanding, without doing the smallest damage.*"

In July 1879, a gasholder belonging to the Dartford Gas Company was destroyed in the middle of the night. The engineer of the Company, Mr. Carvosso, has been good enough to afford me full information regarding this accident, and I have visited the locality. It appears that the holder was established in an above-ground iron water tank, and it seems nearly certain that the accident resulted from the giving way of the walls of the tank, whereby the whole body of water immediately escaped leaving the holder unsealed, and thus enabling the 80,000 cubic feet of gas which the holder contained to escape.

The gas became ignited, whether at the watchman's cottage near, or through a spark struck by the broken or breaking pillars and débris so the holder descended, is uncertain; but even under circumstances so favourable for an explosion, no explosive effects worth speaking of were produced. Indeed, of the two engineers who reported on the case, one expressed his decided opinion that there had been no explosion whatever. At any rate, the "explosion," if there was one, was of such an insignificant character that none of the plates of the holder were projected, but simply bent and rent; and the only fragments which were found at any distance from the holder were those of the tank, and these were scattered about within a radius not exceeding about 17 to 20 yards.*

This case has an interesting bearing upon the Glasgow accident, for whether there was or was not an explosion it furnishes another proof that the ignition of escaping gas would not produce effects in any degree comparable with those observed at Glasgow.

Probably there exist other cases bearing upon this point with which I am unacquainted, but I have not deemed it necessary to expend more time in the investigation of this branch of the inquiry, beyond witnessing a number of experiments which Mr. Foulis, C.E., was good enough to carry out for me. In one set of these experiments gas escaping in torrents under 3″ pressure from a $\frac{3}{4}''$ (internal diameter) pipe was ignited by the application of a torch, without any other effect than a slight dull puff accompanied with blue flame at the point where the stream of gas and the air with which it mixed first came into contact with the flame (about 2′ from the pipe).

In some other experiments a small experimental holder having been filled with the most explosive gas mixture (1 gas to 8 air), the mixture was allowed to issue therefrom under pressure, and was actually set fire to and burnt harmlessly and flamelessly away.†

Assuming a leak to have existed any explosion resulting therefrom could not have occurred at the particular point at which it is certain the explosion occurred in the present instance.

But independently of all the foregoing considerations, which I have only deemed it necessary to explore in view of the interest generally attaching to this subject, there are two yet to be mentioned which appear to me sufficient of themselves completely to dispose of what I may designate the leakage-explosive theory so far as it is connected with this particular accident. They are these: If an explosive mixture of such character as to be capable of producing the effects which were observed at Glasgow could be assumed to have become formed externally to the holder by gas leaking in considerable quantities therefrom, and mixing with the air, it is certain that such a mixture could not have been formed close to the holder, for at that point the gas issuing in torrents under considerable pressure (about $4\frac{1}{2}''$) would have prevented its admixture with the proportion of air which is required to form an explosive mixture.‡

Such a mixture could only become established when the gas had become sufficiently diluted with air, and this would not occur within some feet of the point at which the gas was escaping.§

Again, it would be hardly possible for an explosive admixture of gas and air to be effected in the open at the level of the escaping gas. The rapid ascent of the gas, and its diffusion through the air, would necessarily tend to establish the explosive admixture at some little distance above the point of escape.

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* A good deal of damage was done by the escaping water, large breaches being made in some walls, and people in the neighbouring cottages being washed out of their beds.

† It is hardly necessary to observe that this experiment is one demanding some care and skill, for if there were any failure or insufficiency of pressure the mixture instead of burning harmlessly away would flash back into and explode the holder. But properly carried out the experiment is a very pretty one, and serves to illustrate the *flameless* burning of gas.

‡ As already stated, the maximum explosive power is furnished in the case of the Glasgow gas by a mixture of 1 gas to 8 air; while the limits within which the mixture is explosive range from about 1 gas to $11\frac{1}{2}$ air in one direction to 1 gas to 6 air in the other (*see* page 8, footnote).

§ *See* above as to the experiment with a $\frac{3}{4}''$ pipe, when the ignition or puff which may be regarded as the "explosion" generally occurred about 2 feet from the pipe.

Consequently, it would follow that any such explosion could only occur at some distance from the holder and above the lowest point at which an escape could take place, *i.e.*, above the water in the tank.

But, as a matter of fact, this explosion, as I have shown, undoubtedly occurred close to the holder, between it and the pillar, and immediately above the cup joint, *i.e.*, at the very lowest point possible.

Conclusion as to explosion not having been due to gas.

I venture, therefore, to assert with all confidence that this explosion was not, and having regard to well known physical laws, to actual observation and experience, experimental and other, could not have been due to gas, but must be referred to some other agency.

B. Consideration of question of other explosive agencies.

B.—To what agency (as the explosion was not due to gas), is the explosion to be referred?

While the proof as to the explosion not having been due to gas appears to me quite irrefragable, it will, I think, be possible to show not less conclusively to what class of explosive agent it may be confidently referred.

The effects produced were of a very marked and characteristic description.

(1.) Local character of effects.

(1.) *They were intensely local.*

Thus, as I have shown, the portion of the plate of the holder exactly opposite to the point at which the explosion undoubtedly occurred was blown into small fragments, but the area of *explosive* effect as exhibited on the holder is excessively circumscribed, being limited, indeed, to the shattered upper part of one plate, and to the portion contiguous to it which has been turned back.

Similarly, the length of cup joint affected was small, but for this portion the destruction was complete, as exhibited by the numerous small fragments into which it was blown, and which were subsequently recovered between the sides of the tank and the holder.

Again, while the right cheek of the bracket was blown into very small pieces, the left cheek was uninjured.

The right face of the pillar base, being that immediately opposite the explosion, was cracked, indented, and otherwise marked. The left face was uninjured, and even the paint was scarcely disturbed.

The portion of the stone coping opposite to the point of explosion was considerably defaced, but this effect was limited to about 2′ of the coping.

The condition and position of the portions of the half-round iron stiffener,* and the fracture of the lower part of the guide plate,† afford further evidence of the intensely local character of the explosion, such effects being such as could hardly have been produced except by an explosive acting with detonative rapidity.

(2.) Exceedingly violent character of the effects.

(2.) *The effects were evidently the result of an exceedingly powerful explosive.*

This is shown not merely by the proofs which I have adduced under the first head as to the intensely destructive local action to which the effects were due, but also and very remarkably by the violent character of those effects as measured by the force and velocity with which the débris was projected. I have shown not only that the pieces were driven with such force that a great number of them passed through the top and sides of the holder, and travelled in some instances to distances of from 150 to 200 yards from the point of explosion,‡ but that they were projected with a velocity of which some measure is roughly afforded by the fact that rapidly as the holder fell when an escape was established it had not fallen sensibly before some of the pieces had traversed the distance of 160 feet which intervenes between one side of the holder and the other, and had effected the penetration of this side at a point which at the moment of the explosion is known to have been only just above the water.

Indeed, the facts that at least 77 fragments, some of them, as the holes show, exceedingly small, had been driven through the iron plates of the holder (one row of which was $\frac{1}{4}$″ thick) practically "point blank" at a distance of 160 feet, and that in one case an angle iron $\frac{3}{8}$″ thick was cut clean through by a small fragment § afford a fair measure of the force with which they had been projected. ‖

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* *See* page 6. † *See* page 5. ‡ *See* page 5. § *See* page 5, footnote.

‖ Mention has been made of the little rivet head which was found embedded in the plate on the opposite side of the holder. This rivet head weighed only 129·06 grains and measured about $\frac{7}{16}$″ diameter. It must have been projected with very great velocity to travel across the holder (160′) nearly point blank and become embedded in the plate on the other side.

Marked concentration of projectile matter of left.

It may be useful to recur to the point which has been before remarked upon, as to the projectile matter on the right having been much more scattered than that on the left.*

This is doubtless due to the fact that on the left the explosion was directed to a very great extent by the right cheek of the bracket, whereas on the right there was nothing to confine the action of the charge, with the result that the fragments on this side were much more dispersed in their forward flight. In short, it is scarcely fanciful to regard the explosion as having been fired from an imperfect gun, or a gun divided vertically in two parts down its longer axis, and having the whole of the right portion deficient. Consequently the shooting was closer on the left than on the right, and this incidentally adds to the testimony as to the force and velocity of the explosion.

Peculiar pitting effect in neighbourhood of explosion.

(3.) The peculiar pitting of the stone and iron which had been produced in the immediate vicinity of the explosion, viz.: on the stone coping of tank, the front of the pillar base, the right side of the right cheek of the bracket; the right inner and right outer sides of the guide plate, and on pieces of the cup joint, holder plate and rivets,† was eminently characteristic of the action of a very powerful explosive enclosed in a metal case.

Professor Abel, C.B., F.R.S., has obligingly furnished me with a piece of interesting corroborative evidence on this point. He has shown me a malleable iron plate $\frac{1}{8}''$. thick which he had employed in the course of some experiments which were being carried out to measure the effects of dynamite, and over which a suspended charge of 5 lbs. of dynamite enclosed in a thin tinned iron case had been exploded at a distance of 4′, the plate resting upon an annular anvil. The result was not only to pit the plate with numerous irregular marks, but to pierce it in many instances, and Professor Abel has employed this plate to illustrate the extraordinary rapidity of action of dynamite, which is capable of thus indenting and even penetrating $\frac{1}{8}''$ of iron with pieces of the thin tin plate enclosing case projected at a distance of 4′ from it.

Professor Abel having furnished me with a photograph of the back and front of this plate, I have thought it useful to annex it to this Report (*see* photograph No. 7).‡

Now, in the case of the explosion at the Glasgow gasholder the metal in the vicinity of the explosion was pitted exactly in the same way as this plate,§ and this effect is so characteristic of the explosion of a very powerful explosive enclosed in a metal case and acting with detonative rapidity‖ as to be in itself conclusive as to the explosion having been effected by an agency of this sort.

Character of the sound of the explosion.

(4.) The character of the sound of the explosion was that of a *detonated* explosive. From all the evidence which I have been able to collect on this point, it appears certain that the explosion was of a sharp. well-defined character, "like a gun going off," or "like a blast in a quarry," while as already stated, it was sufficiently loud to have attracted attention at 4 or 5 miles.

The witness. Gibson, who was at the governor house, states that he was for some time engaged at the Eglinton Ironworks, where he became familiar with the sound of dynamite blasting, and this explosion, he states, was exactly of a similar character.

Grounds for concluding that explosion could not have been that of gunpowder.

(5.) The explosion could not have been that of gunpowder because, (*a*) gunpowder would not have produced the violently local and powerful projectile and pitting effects which were produced here; and (*b*) an explosion of gunpowder would have been attended with a large volume of smoke, which in the dry clear night could not have escaped observation.

Examination of question whether coal gas could be ignited by a charge of detonated dynamite.

(6.) Lastly, assuming that a hole had been blown in the side of the holder by the detonation of a charge of some nitro compound close to it, and this hole having become enlarged by the ripping off of the plates as the lift descended, would the ignition of the escaping gases have been likely to follow?

As to this I have consulted Professor Abel, who, I was aware, had had large experimental experience which would be likely to furnish useful data for the determination of this question. Professor Abel has written me a letter, which I think it desirable to quote *in extenso* and which establishes quite conclusively that coal gas can be exploded by dynamite near to it. And if a large body of igniting gas were issuing from a huge opening in the side of the holder, the ignition of the gas issuing from the holes formed by the projectile matter through the top of the holder would necessarily immediately follow. The letter is as follows:—

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* *See* page 7.

† *See* pages 5, 6.

‡ It has not been thought necessary to reproduce the photographs for the purposes of the printed report.

§ That it was not actually penetrated is probably due to the fact that it was much thicker. But of course it is not impossible that some of the pieces of plate, many of which were not recovered, were so penetrated.

‖ Professor Abel informs me that he found this effect so invariably occurred more or less when a tin case was employed, and that it so interfered with his observations as to induce him ultimately to give up altogether the employment of a metal case and to use an unconfined charge for the purposes of his experiments.

"A series of experiments recently made by me, and by Mr. Robert Galloway, of Cardiff, at my instigation, with a view to the diminution of risks attending the employment of explosive agents in coal mines, enables me to give a conclusive and affirmative reply to your inquiry whether coal gas, on mixing with air, can be inflamed by detonating dynamite in proximity to it.

"In order to ascertain whether the explosion of a blast hole charged with dynamite and having superposed tampings, would be likely to be attended by disaster in a fiery mine, where the air might, in the neighbourhood of the charge, be mixed with fire-damp to an extent to be explosive, and whether, in that event, the liability to accident might be guarded against by the adoption of particular arrangements which had suggested themselves to me, experiments were instituted of the following kind.

"Charges of three ounces, and upwards, of dynamite were placed and tamped in the usual manner, in blast holes made in clay, cement, or granite, in vertical positions, so that a simple arrangement might be placed over the blast hole, for retaining an explosive mixture of coal gas and air, into which the force of the explosion would be mainly directed, as in the case of a so-called blown out shot. The receptacle for retaining an explosive gas mixture over the blast hole, consisted of a large (4 feet cube) light, gastight, structure, open at the base, which was placed over the blast hole; when this had been charged, fitted with an electric detonator, and tamped, the tube was filled with the explosive gas mixture, which was prevented from escaping at the base of the reservoir by applying clay tamping all round.

"With *three ounces* of dynamite in a blast hole 2 feet 6 inches and 3 feet deep, and tamped with clay or sand, the ignition of the coal gas mixture followed immediately upon the detonation of the charge, the gas reservoir being projected upwards in a more or less torn condition, with the production of a large volume of flame. This result was many times obtained. On the other hand, when the same weight of dynamite was used, the blast-hole being charged with it in a particular manner, its detonation, provided certain conditions were properly fulfilled, caused the gas reservoir to be projected upwards, but in an uninjured state, so that it might be used in further experiments, and no flame was visible.

"These experiments demonstrate that even so small a charge as three ounces of dynamite with a considerable interval of powerfully resisting material between it, and a mixture of coal gas and air, will, by its explosion, bring about the ignition of the gas mixture."

Conclusion as to explosion having been occasioned by a charge of an explosive of nitro-compound class.

Accordingly, I conclude without any hesitation that the explosion—

A. Was not an explosion of gas; but

B. Was the explosion of some powerful explosive probably of the nitro-compound class[*] detonated in the space between the pillar and the 12th plate from the top of the outer lift, and immediately over the cup joint (probably resting upon it) and to the right of the bracket.

There is, I think, no reason to doubt that all the observed effects could have been produced by a charge of about 5 lbs. of well-made dynamite applied as suggested,[†] though whether the agent actually employed was dynamite, or blasting gelatine, or gun-cotton, or lignin-dynamite (imported or manufactured for the purpose), tonite or potentite, or some other variety, it is impossible to say in the absence of more precise indications than we at present possess.[‡] That it was some explosion of this class I have no doubt whatever.

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[*] The same effects could have been produced by some explosives of the chlorate mixture class, but as these are not practically in use it is much more probable that an explosive of the nitro-compound class was employed.

[†] In some experiments which Professor Abel and I carried out last year at Chatham, when a charge of 2 lbs. of dynamite was exploded against a ½″ iron plate of a vessel, a ragged hole 18′ × 8½″ was blown through the plate. It is worthy of notice that when this experiment was repeated with 8 lbs. of gunpowder (instead of 2 lbs. of dynamite) no effect whatever was produced, the plate not even being bulged.

[‡] I have taken some pains, with the assistance of Dr. Dupré and of Mr. MacRoberts, Works' Manager of Nobel's Explosives Company, to ascertain whether any remains of the inert ingredients of dynamite were discoverable on the pieces of iron in the little pittings, &c., but have failed to find anything of the sort. Such failure, however, by no means negatives the possibility of the agent employed having been dynamite, for it would be very unusual to find any remains of dynamite if it had been properly detonated.

As to mode of explosives adopted.

Having shown to what cause the explosion and resulting fire were due, it is scarcely of much practical importance to inquire into the particular method by which the explosion was effected. That the explosive was detonated the observed effects sufficiently establish. But whether the detonator was exploded by means of an electric fuze fired from a distance, or by the ruder method of a long piece of ordinary blasting fuze, or by some special arrangement, it is not possible to say with certainty.

Pieces of tape recovered in vicinity of explosion.

But as bearing on this point, my attention has been particularly directed to two pieces of tape which were found after the explosion to the north of the cracked pillar, and distant from it respectively 60′ and 110′, at the points marked 14 and 13 on the plan. (*See* plate No. 1.)

I have examined these pieces of tape very carefully in conjunction with Dr. Dupré, and we have also had the benefit of the assistance and experience of one of the leading safety blasting fuze makers, in which trade such tapes are extensively employed. We have also compared the tape with a number of pieces of tape from samples of insulated telegraph wires with which the Silvertown Company have been good enough to furnish me for the purpose. But I regret to say that it has been impossible to come to any decided conclusion on the subject. That the tapes have formed the spiral coverings of a cylindrical core there can be no doubt from their shape and from the way in which they are marked; and as the tapes exhibit two distinct sets of marks, one crossing the tape slant-wise, and the other nearly at right angles, it seems to follow that they must have formed the inner tapes of a doubly-protected cylindrical body, such as certain descriptions of a safety fuze and telegraph wire. Again, the tapes correspond exactly as to quality and make with those on certain makes of safety fuze, and the slanting marks lie across the tape at exactly the same angle as the slanting marks on those particular makes of safety fuze, while in the case of the protected telegraph wires the marks are much more slanting.

On the other hand, absence of any trace or even smell of tar in the tape (even allowing for its exposure to weather and rain for 2 or 3 days)* would seem to negative its having formed part of a safety fuze of the description ordinarily employed in this country, and the presence (as ascertained by Dr. Dupré) of a small amount of paraffin or ozokerit would tend rather to connect the tape with some sort of telegraph wire. But beyond this we are unable to carry our suggestions. The tapes had most likely formed part of the covering of either a safety fuze (though not in all respects of the ordinary English make) or of a telegraph wire (though not exactly of the make of any of the samples supplied by the Silvertown Company).

If the tapes originally formed part of a safety fuze they had certainly been unwound before the fuze was fired, and may have been so unwound from the end near the charge, in order to attach the fuze and detonator tightly to the charge, and so to ensure success.

As bearing on the subject of the possible employment of a fuze, I may mention that I observed on the stone coping near to where the charge had been applied a mark or streak, such as a safety fuze would be likely to make in burning over white stone. The mark was exceedingly faint, and I am not prepared to pledge myself that it had been occasioned as I have suggested, but it had that appearance.

Some weeks after the explosion there was recovered in the neighbourhood of the holder a small brass cap, somewhat disfigured. I did not attach any particular importance to this cap at the time, but circumstances which have occurred while this Report has been going through the press induced me again to examine this piece of brass, and I came to the conclusion that it was almost certainly a part of an arrangement similar to that which there can now be no doubt was employed on the Possil Bridge to fire the detonator, and which will be more particularly described in connexion with that explosion.† If this be the case, it would seem to point clearly to the explosion having been brought about, like that on the Possil Bridge, by a special apparatus, though the comparatively slight injury sustained by this brass cap presented a difficulty. But failing some admission hereafter by one of the perpetrators of the outrage, should they hereafter be captured, it is unlikely that this point will ever be satisfactorily cleared up. At any rate, the means at my disposal at present are scarcely adequate to support any very decided conclusion as to the particular method of ignition employed.

Favourable condition of the locality for the commission of such an outrage.

I cannot refrain before concluding this part of my report from pointing out that the spot selected was peculiarly well adapted for the commission with impunity of such an outrage.

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* These pieces of tape were not found for more than 48 hours after the explosion, during which time there had been a good deal of rain.

† *See* page 20.

In the first place, the gasholder stood, as has been explained, in an isolated position away from the body of the works, and it was not specially guarded.

In the second place, Muirhouse Lane, which bounds one side of the plot of ground in which the holder was situated, is a little frequented lane, without a single gas lamp, and one where in the shadow of the high wood stacks or among the sheds and outhouses an evil disposed person could easily conceal himself.

Thirdly, the lane is separated from the ground on which the gasholder is situated by no better protection than a wooden fence, easily surmounted, but still more easily passed through after one or two of the upright wooden palings have been removed. And it is noteworthy that as a matter of fact two palings were after the explosion found to have been removed near the end of the palings towards Lilybank Road, and these particular palings Gibson asserts most emphatically had not been removed at 7 p.m. on the night of the explosion.

Fourthly, the particular point of attack selected was favourable to concealment (*a*) because it was at a part of the holder on the side away from Lilybank Road, away from the governor house, away from the gatehouse, and not in the immediate vicinity of either the inlet or outlet valves, nor did it lie in the path of the man at the governor house whose duty it would be to visit these valves from time to time, and (*b*) because it was very near the fence into Muirhouse Lane, so as to admit of ready entry and exit; and (*c*) because the side of the pillar which was selected (the right) secured to the person laying the charge the protection from view from Lilybank Road and from the greater part of Muirhouse Lane which the large pillar was calculated to afford.

In short, I am of opinion that it would have been difficult, if not impossible, to select a more favourable spot for the commission of such an outrage round the whole circumference of the holder.

It forms, however, no part of my duty to examine what I may distinguish as the detective aspect of the question. It must rest with the police to follow up such clues as they may have been able to obtain in order to bring to justice the perpetrators of what there can be no doubt was a deliberately planned and carefully executed outrage, and it is to be hoped that the reward of 500*l.* offered by the Glasgow Corporation, and the promise by the Lord Advocate of free pardon for anyone not being the actual perpetrator will have the desired effect.

It remains for me only to acknowledge, which I desire to do most gratefully and fully, the very great assistance which I have throughout my inquiry received from Mr. Foulis, C.E., the engineer of the Corporation Gasworks, as well as from the other officers and servants of the Corporation with whom my duties brought me into contact.

II.—*Explosion on Possil Road Canal Bridge.*

Second explosion (on canal bridge over Possil Road).

Rather more than two hours after the explosion at the gasworks (viz., about 12.30 a.m.) on Sunday, 21st January, a second explosion occurred, the circumstances attending which were, however, not such as to attract general attention at the time. Indeed, as will presently appear, the explosion, which it cannot be doubted had been intended to be of a very formidable and destructive character, practically "missed fire," and it is probable that what actually took place was simply the explosion of the detonator (perhaps with a primer attached) by which the main charge was to have been fired, followed by the burning of a portion of the charge.

Circumstances of explosion.

The circumstances were as follows:—

A party of four men and two women (named respectively Adam Barr, Matthew Barr, Archibald Barr, George Gee, Janet Richardson, and Janet Watson) having spent the evening together at the house of Janet Richardson in Wigton Street, were proceeding from Glasgow towards Springburn shortly after midnight on Saturday the 20th January. On arriving upon a bridge or aqueduct which carries the Forth and Clyde Canal across Possil Road, their attention was attracted by a box standing about the middle of the bridge a foot or two from the side of the canal. Adam Barr (a soldier on furlough) at once went up to the box, which proved to be an ordinary oval-shaped japanned tin bonnet box about $11\frac{3}{8}$" high by $17\frac{3}{4}$" in one diameter, and 12" in the other. Adam Barr is said to have lifted the box and carried it a few paces, when he laid it down and opened the lid, and observed that it was filled with a substance "like brown sand;" and it is further stated that on his touching the substance it began to fizz, and this fizzing was in a very short time succeeded by an explosion, accompanied by a vivid flash.* Matthew Barr states that he was knocked down by the explosion, and five of the party sustained slight injuries from being cut by some small pieces of projected metal.

The account given by the witnesses although consistent is not very precise in its details.

Independently of the difficulty which usually attaches to any attempt to reproduce with rigorous fidelity all the circumstances attending so discomposing an event as an explosion which suddenly takes place in one's immediate vicinity, the difficulty in this case is enhanced by the fact that some of the party at any rate were more or less under the influence of liquor.

I am not therefore particularly concerned with their estimate of the time which elapsed between the contents of the box beginning to fizz and the explosion, of the nature and degree of brightness of the flash, or as to the duration of the burning of the material after the explosion; nor do I consider that implicit reliance is to be placed on their statement that no fizzing was heard before Adam Barr began to stir up the "brown sand," or that one of the party was actually "knocked down," by the force of the explosion.

The broad facts, however, are indisputable:—That a tin box of the sort and size stated and containing a considerable quantity of a material which, as I shall presently show, was undoubtedly a nitro-compound, was found in the middle of the night on an aqueduct where its explosion, if it had accomplished the destruction of the bridge, would have released the canal water into the streets below and thus produced grave consequences and much public alarm.

It is equally beyond dispute that there was a slight explosion of some sort, which may probably be referred to the detonator (with or without a small priming charge attached) intended to explode the main body of the material.

Lastly, there can be no doubt of the fact that the contents of the box continued burning for some little time (the witnesses say a quarter of an hour) after the explosion, during which time, as the alarm which the explosion had created wore off, the party kicked the box about and some of the material which it contained was thrown out unburnt.

The police were promptly communicated with, and the box and some of the spilt explosive and four little pieces of brass which were found in the neighbourhood of the box were taken charge of by them.

The injuries which the Barrs and their friends had sustained proved very slight,† and were attended to.

Examination of objects recovered from the bridge.

I have had an opportunity of carefully examining the box, the recovered explosive and the pieces of brass, and have also submitted them to Dr. Dupré for his examination.

Box.

The size, shape, and general features of the box I have already described. The japan was much charred particularly on the inside. The lid was detached, the hinge having been probably torn off after the explosion. In the lid is an elongated hole evidently made with some sharp instrument and not by an explosion. The box itself showed no signs whatever of injury by explosion, being simply somewhat disfigured by blows from the outside. Inside the box was some charred material which on examination proved to consist chiefly of partially burnt wood, but among it was some unburnt wood in which was absorbed some nitro-glycerine.

Explosive.

The spilt and unburnt explosive which was recovered had the following composition:—

Sawdust and a little charcoal	75·4
Nitro-glycerine	19·2
Moisture	5·4
	100·00

It was, in fact, a description of explosive to which the designation "lignin-dynamite" has sometimes been given. Explosives of this sort have been used in America and elsewhere, but they are not in lawful use in this country and have never been licensed for use in or importation into the United Kingdom. The explosive therefore could not have been drawn from any store or magazine in the United Kingdom, but must have been specially and illegally made or imported.*

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* It appears that the explosion was heard at least 300 yards, for a policeman on duty at about that distance from the bridge heard it, and another policeman about 200 yards off heard it.

† That they were neither very much hurt nor very much frightened is, I think, proved by their kicking the box about while the contents were burning.

(While this Report has been going through the press two more discoveries of "lignin-dynamite" in connexion with intended outrages have been made, viz., in the case of the attempted explosion at the "Times" office, in Play House Yard, London, on the 15th March 1883, and in the case of the two infernal machines which were recently seized at Liverpool. In both these cases the explosive was "lignin-dynamite.")

The spilt and unburnt substance recovered on the Possil Bridge corresponded to the unburnt remains which were recovered from the inside of the box, and there can be no doubt from this fact and from the fact that the charred remains in the box were composed mainly of partially burnt sawdust, that the original contents of the box consisted of the same explosive as was afterwards scraped up from the bridge.†

It may be stated that the substance was very slightly explosive by percussion, and that it burnt feebly with at first a pale greenish flame. It was, considered as an explosive, a poor article, and it appeared to have been exceedingly imperfectly made, as is shown by the fact that the remains of organic impurities had not been removed from the wood. This may have been due to hurry, defective appliances, or ignorance, or the three combined.

Pieces of metal.

I took a great deal of pains to ascertain whether there was any reasonable probability that the pieces of metal which were recovered on the bridge had been in any way connected with the explosion.

One of them has been identified by competent persons as the lubricating cup of a stationary or locomotive engine, another piece it was thought probable may also have formed part of a lubricating contrivance, though the type does not appear to be a well-known one; another piece consisted of a brass cap tapped internally, and with a hole in the bottom, the fourth piece was a small brass article not dissimilar in size and shape to a collar stud; neither of the two last named pieces can be identified, and the fourth does not appear to have had any connexion with the other pieces.

At one time I had come to the conclusion that it was improbable that none of these pieces of brass were in any way connected with the explosion. It was not easy to see how they could be applied to this end, nor why the complicated arrangement which they appeared to suggest, should be preferred to the simpler and well-known and easily procured miners' fuze and detonator.

But the recent discovery at Liverpool (while this Report has been going through the press) of some exactly similar pieces of brass in immediate connexion with two infernal machines, has thrown quite a new light upon the subject, and Dr. Campbell Brown having set himself to ascertain in what manner the apparatus could be usefully employed in combination with some ingredients, viz., chlorate of potash, sugar, red orpiment, and sulphuric acid, which were included in the same seizure, worked out very satisfactorily and conclusively the intended application of the tubes. He showed that by introducing sulphuric acid into the top part of the tube, which is furnished with a tap, and by placing a small charge of chlorate of potash, sugar, and red orpiment in the space below the tube which contained the sulphuric acid, the first step would have been taken towards applying a well-known igniting arrangement.‡ The tube in which the sulphuric acid was placed contained a hole, and this hole was intended to be (and in the Liverpool case actually was) closed by folds of paper wrapped tightly round them. A detonator could be introduced into the hole at the bottom of the tube, below the chlorate of potash mixture. When the operator had deposited his machine, all that would be necessary would be to turn the tap and allow the sulphuric acid to flow down the tube; it would at once commence eating through the paper, and it would depend upon the nature of the paper, the number of the folds, and the tightness with which it was wrapped, how long a time would elapse before the paper was completely eaten through.§ Directly the paper was eaten through the sulphuric acid would come into contact with the chlorate of potash mixture, which would at once inflame and fire the detonator. In short, the arrangement may be described as a slow-action or deferred-action fuze, which admits of ready adjustment at the will of the operator, and which possesses to a person engaged in the commission of an outrage this special merit, that no fire or light has to be applied, and thus the chance of detection and failure are by so much diminished.

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* The manufacture or importation of any such explosive cannot be lawfully undertaken without a license (Explosives Act, 1875).

† One of the witnesses (Archibald Barr) also stated that the substance in the box "looked like sawdust or wood fibre."

‡ The method of procuring ignition by bringing sulphuric acid into contact with a mixture of chlorate of potash and sugar was used for many years with the "Coas Guard Port fires," the sulphuric acid being contained in a glass globule, which was embedded in the chlorate mixture, and broken when ignition was desired to be effected. Hence the occasional name of "percussion port-fires" (Treatise on Ammunition, 1st edition, pp. 215–216).

§ Dr. Dupré has found experimentally that the time may be regulated from 4 minutes to 40 minutes; and I believe Dr. Campbell Brown obtained similar results.

From the Liverpool discoveries and from other information which has come to my knowledge, I consider there is now no doubt that the pieces of brass recovered on the Possil Bridge had formed part of an apparatus intended to be used in this way, and, indeed, Dr. Dupré has found in the tube evidence of the presence of sulphuric acid, and some remains of what there can now be little doubt was the burnt paper and residue of the chlorate mixture.

Pieces of solder.

There were a few small pieces of white metal found on the bridge which were also no doubt connected with the explosion. These on examination proved to be pieces of solder, more or less globular in form and such as are frequently found adhering to soldered articles, particularly if the soldering has been unskillfully done. The connexion of these with the explosion seems to be established by the fact that they had adhering to them small particles of the partially charred sawdust exactly similar to what was found in the box.

They doubtless had formed portions of the soldering of the metal case which it may be surmised contained the fulminate or the primer by which the explosion which injured the persons on the bridge was effected.

Conclusion that the affair was a deliberate attempt by some evil disposed person to destroy the bridge.

We have here then ample evidence of a deliberate attempt to bring about an explosion with a considerable quantity* of an explosive specially though clumsily prepared; and it is reasonable to assume that the destruction of the canal bridge is what was aimed at.

It only remains for me to consider how this evil intention was happily averted.

Consideration of possible causes of failure of attempt.

It is possible that the removal of the lid by Barr disturbed the igniting apparatus (which was probably introduced into the box through the slit in the lid, of which mention has been made), and it may be that some of the sulphuric acid became spilt, and acting upon some of the lignin-dynamite, produced the fizzing sound and inflammation, and probably also the detonator became involved in the ignition, and exploded about the same time.

Or, by a mere coincidence, the sulphuric acid may have reached the chlorate mixture at the precise moment that Barr lifted the lid, and the fizzing in that case would no doubt be that of the chlorate mixture, to be immediately succeeded by the explosion of the detonator. If the raising of the lid had removed the detonator for the moment to a short distance from the body of the "lignin-dynamite," the effect might easily be the mere ignition of the dynamite.

Or a similar effect might have resulted from the use of an insufficiently powerful detonator, even if it exploded in contact with the dynamite.†

But it is not really essential for the purposes of this inquiry that we should know exactly why the explosive did not explode as it was intended to do, or what were the particular conjunction of circumstances which fortunately rendered the enterprise abortive.

It is sufficient to know beyond all doubt that great pains had been expended by some evil-disposed person or persons to produce an explosion which, if it had accomplished what was evidently intended, would have occasioned very great loss and damage, and much public inconvenience.

Who those evil-disposed persons were, and what were the motives which influenced them, are points which fall outside my province, and the duty of investigating which belongs strictly to the police.

III.—*Explosion in Shed of Caledonian Railway Company.*

Third explosion (shed belonging to Caledonian Railway Company near Buchanan Street Station).

The third explosion which I am required to report upon occurred at 1.15 a.m. on the morning of Sunday, 21st January, in a shed in the yard of the Caledonian Railway Company near Dobbies Loan.

Description of shed and

The shed was 196 yards beyond the nearest point of the passenger platform of the Buchanan Street Station, on the left of the line, and 35 yards beyond Dobbies Loan Bridge, which crosses the Railway between Buchanan Street station and the shed.

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* If the box were full it would probably contain about 10 or 12 lbs. of lignin-dynamite of the density of that which it had contained.

† *See* Report dated 30th October 1878 on the explosion at Carn Brea Mine, page 7, where this effect is discussed.

Surroundings. The shed was built of 9″ brickwork, with a slated roof, and was about 29′ 6″ × 15′ 6″, the floor being raised about 4′ above the ground, and prolonged to the south-east beyond the shed so as to form a coaling platform, on which stood a crane which had been used for coaling purposes.

The floor also extended about 3′ along the outside of the shed on the south-west so as to form a sort of external gangway, which was covered.

The shed had two 6′ doorways and one 4′ doorway on the north-east side; there was a large doorway (7½′) opening from the shed on to the platform at the south-east end; and there was a 4′ doorway, and two windows on the south-west side. There was no opening at the north-west end of the shed. All the doorways were unprovided with doors, and the glass in the windows had all been broken before the accident, at which time the shed was wholly in disuse. The shed had been used for some years for coaling locomotives, the coals being deposited before coaling in wrought iron boxes which were run out on to the coaling platform. There was also a press for keeping oil; but about three months before the accident the shed had been abandoned, when this press and everything that the building contained were removed, the doors even being taken away from the doorways, and the shed left an empty shell.

The space underneath the floor was entered by a manhole near the east corner. This space had not at any time been used for the storage of goods, but after the accident there was discovered near the north corner a box containing a number of valuable locks belonging to the Inland Revenue, and supposed to have been stolen, which box had no doubt been placed under the floor for concealment, a circumstance which incidentally furnishes some confirmation of the fact that the shed had been placed in complete disuse, as it otherwise would hardly have been selected as a place of concealment for stolen property.

Opposite to the north-west end of the shed stood, at a distance of about 4 yards, a brick building, of which the part immediately facing the shed was used as a "bothy," or shelter house for the workpeople, while the main building was used as an engine shed.

Along the north-east side of the shed was a light subsidiary wooden shed with tarpaulin roof, to afford shelter to the men engaged in coaling; and beyond this was a large engineering shop, occupied by Messrs. Laidlaw and Co. To the east of the shed, and distant about 8 or 9 yards, was a small brick shed.

To the south-west of the shed were the lines of rails.

The débris had not been materially disturbed when I visited the spot on the 24th January in company with the Procurator Fiscal (Mr. Brown), the police, and some representatives of the Company.*

I also made a careful examination of the spot the following day, when by my directions the débris had been cleared away so as to admit of the condition of the shed and its immediate surroundings being better seen.

Effects of explosion. The effects of the explosion had been to completely destroy the shed, the walls of which down to about the level of the floor were wrecked and the material composing them, and the roof has been projected in different directions.

The floor joists were broken downward along a line extending roughly from near the east corner to about the centre of the north-west end. Some of the planking of the floor was also shattered along a corresponding line, and parts of the planking were not merely broken but splintered, and the wood in places macerated. The destruction was most complete towards the north-west end of the shed; and it was in this direction that the most violent effects had been produced outside the shed. Thus, a quantity of bricks had been projected with considerable violence against the wall and door of the "bothy," and immediately over the door a piece of projected débris had completely penetrated the brickwork, making a jagged hole about 19″ to from 10″ to 15″.

The engine-house itself had not suffered beyond the breaking of windows and the forcing open of the doors.

To the south-west a quantity of bricks, slates, and other débris had been thrown on to the line, to distances (I was told) of about 30 yards.†

The shed to the south-east had the door blown in and broken, the windows broken, some slates stripped, and the interior injured in a way which would naturally have been expected in the case of a building standing only a few yards from a sharp explosion.

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* It had of course been necessary in order to allow of the traffic proceeding to remove the projected bricks, slates, and pieces of plank from the rails on to which they had been thrown.

† This part of the débris had necessarily been removed (to clear the rails) before I arrived.

The engineering shop to the north-west had the windows broken. The intervening shed or "lean-to" was demolished, but the débris of this shed did not appear to have been projected with any great violence.

Windows are said to have been broken at some little distance from the scene of the explosion, which was described to me by more than one witness as having been very sharp and well defined, and unaccompanied by any smoke, or at any rate no such volume of smoke as would have resulted from an explosion of gunpowder.

The explosion was observed by Thomas Smith and two enginemen who were on their respective engines at about 60 to 70 yards from the shed where the explosion occurred.

Consideration of possibility of explosion having been due to gas or petroleum vapour.

I directed my inquiries to the possibility of the explosion having been caused by an escape of gas, by an accumulation of gas from coals possibly remaining in the shed, or by an accumulation of benzoline vapour.

I satisfied myself that any such explanation of the occurrence would be quite untenable.

In the first place, although the shed and platform had at one time been lit with gas, the supply had been cut off when the use of the building was abandoned; and the evidence as to the use of the shed as a store for coals or oil or any other articles, having been given up about three months previously was quite distinct and reliable.

In the second place, even if it has been possible for gas, whether from a pipe or from coals, or vapour from mineral oil, to be given off in the shed, its accumulation in such a manner as to form an explosive mixture would have been almost a physical impossibility, owing to the exceedingly open character of the shed, with its five open doorways (three of which were of unusually large dimensions) and its two (broken) windows.

That the explosion could not have arisen from any such accumulation in the more confined space below the floor is quite evident from the facts (*a*) that the floor is broken downwards by a force operating from above; and (*b*) that the walls below the floor line are relatively uninjured.

Even if the foregoing difficulties could be disposed of, we should still be left with the difficulty, by no means an inconsiderable one, of explaining the ignition of the accumulated gas or vapour.

These substances could not go off without the direct application of fire or flame in some form, and I have failed to find in the surrounding circumstances any satisfactory explanation of how such fire or flame could have been accidentally present to procure such ignition; while the fact that no one was hurnt or injured is sufficient proof that the ignition was not caused by any one taking a candle or lamp into the shed and so firing an accumulation of gas or benzoline vapour.

Lastly, the effects produced were not such as it would be reasonable to attribute to an explosion of gas or petroleum vapour mixture.

For although conceivably such a mixture might if exploded wreck a building and make itself sensible in the breaking of windows, it is scarcely conceivable that it would (*a*) have projected débris through the brick wall of a neighbouring building, or (*b*) fracture and splinter and even macerate the wood of the floor planks in the manner in which they have been fractured and splintered in this instance; (*c*) I am also disposed to think that an explosion of this character would certainly not have been so loud, sharp, and well defined as this one is described to have been.

On the other hand, all the observed results are not only consistent with but would be normal to the explosion of an explosive of the dynamite class.

Evidence as to intensely local character of explosion.

Very noticeable evidence as to the intensely local effect of the explosion and as to the agency by which it was accomplished is furnished by the fact that portions of the floor planks which I examined, and other portions examined by Dr. Dupré, exhibited a number of deep irregular marks, from the bottoms of several of which we were able to pick out a quantity of small irregular shaped pieces of metal which proved on examination to be pieces of thin tin plate, which had evidently been driven into the wood and embedded therein, in some instances to the depth of over an inch.

We also found one piece of metal considerably larger than the rest, which had been driven in to a depth of fully 1 inch. This proved to be a piece of wrought iron.

I am not able to suggest what this last piece may have been, but it was clear that it had been driven into the wood by some powerful force, such as could hardly have been applied by any agency other than that of a quick-acting explosive. And in the case of the small pieces of tinned iron Dr. Dupré and I are agreed that their presence in the wood is hardly to be reasonably explained except on the assumption that they had formed portions of a tin canister or box which had been blown to pieces by an explosion of some nitro-compound,* and so driven in small fragments into the wood. In short, they had doubtless borne the same relation to the explosive employed as the pieces of metal by which the pitting of the iron plates, bracket, pillars, and rivets and the stone coping at the gasworks had been effected.†

What had amounted to "pitting" only on metal and stone became deep penetrations, an inch or more deep, in wood, and while the metal and stone threw off the pieces of tinned iron plate by which it was attacked and marked, the wood absorbed and retained them.‡

Dr. Dupré very carefully examined the broken planks with a view to discovering some remains of the inert ingredients of a nitro compound, such as the kieselguhr of ordinary dynamite or the unconsumed wood of "lignin-dynamite," but without success.§ In the absence of any such definite indications it is not possible to say what particular description of explosive was employed, whether nitro-glycerine, or dynamite, or lignin-dynamite, or gun-cotton.

Conclusion as to nature of explosive employed. Explosion doubtless wilfully effected.

But, having regard to all the circumstances of the case, I feel no hesitation in expressing my very decided opinion that this explosion was without doubt effected by some explosive of the nitro-compound class, an opinion which I fear must be regarded as pointing to the further conclusion that such explosive was certainly wilfully applied by some evil disposed person.

If it be unreasonable to suppose that gas (assuming any to have existed) could have become accidentally ignited, it would be still more unreasonable to suppose that an explosive of the nitro-compound class, which requires a detonator and special appliances to explode it, could have been present and gone off by itself. And there can, therefore, I regret to say, be no doubt that the explosion was deliberately planned and effected.

It may be worth while to state that from experiments carried out by me against a masonry structure in 1881, I am disposed to conclude that if dynamite of ordinary quality was employed on this occasion, the amount probably did not exceed about 5 lbs., while from the character of the effects I should think it certain that the charge (enclosed in a tinned iron box or canister) was placed on the floor, towards the west corner or the north-west end.

It forms no part of my duty to enquire into the motives which may have actuated the perpetrators of this outrage, whoever they may have been. This is an aspect of the question which falls to the police and not to me to explore.

But it may not be out of place to mention that after the explosion, a ladder was found set against the wall at Dobbies Loan bridge into the yard near the explosion, by which a person bent on blowing up this shed could easily have had access to and returned from the spot. Such a means of approach did not I am informed ordinarily exist (though there had been an iron ladder here up to the time of the disuse of the shed) and it could hardly have got there accidentally.

I have the honour to be,
Sir,
Your obedient servant,
V. D. Majendie, Colonel,
H.M. Chief Inspector of Explosives.

The Right Hon. the Secretary of State,
Home Department.

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* They may possibly have been acted upon by a fulminate explosive (*e.g.*, if they had formed part of a detonator), but in that case I am disposed to think they would have been much smaller than were some of the recovered pieces.

† *See* page 15.

‡ We also examined some bent and broken pieces of tinned plate which were found among the ruins, but these pieces were not only much larger but thicker than the pieces picked out of the wood, and it was evident that the box of which they formed part had not been acted upon by an explosion from within but from without.

§ The absence of these indications is, however, no absolute proof as to the non-employment of dynamite or lignin-dynamite, for from experiments which I have made it appears that in the case of ordinary dynamite the inert absorbent material which it contains is so completely broken up as to be unrecognisable, even with the aid of a powerful microscope.

APPENDIX A.

INVENTORY OF PIECES OF IRON found in the vicinity of GASHOLDER TANKS at TRADESTON, being parts of the GASHOLDER damaged on the 20th January 1883, at 10.15 p.m.

Numbers refer to Reference Numbers on Plan.

No.	—	REMARKS.
1	Piece malleable iron plate $9\frac{1}{2}'' \times 2\frac{1}{4}'' \times 1\frac{1}{4}''$	Probably piece off side of gasholder.
2	Piece malleable iron plate $\frac{1}{4}''$ thick $\times$ $3\frac{1}{2}''$ long, $1\frac{1}{2}''$ broad at one end and 1" broad at the other. Deeply pitted on one side.	Piece of side plate of gasholder.
3	Piece malleable iron plate $4'' \times 1\frac{1}{2}'' \times$ No. 12 B.W.G.	Probably from roof of holder.
4	Piece malleable iron plate $2\frac{1}{2}'' \times 1\frac{1}{2}''$	—
5	Piece malleable iron plate $10'' \times 6'' \times \frac{1}{4}''$ smooth on edges, pitted at one end.	Evidently a piece of side plate of holder near point of explosion.
6	Piece malleable iron plate $2'' \times 1\frac{1}{4}'' \times \frac{1}{4}''$ smooth on edges.	Do. do.
7	Piece malleable iron $2'' \times 1\frac{1}{2}'' \times$ No. 12 B.W.G.	Probably from roof of holder.
8	Piece malleable iron $12'' \times 6'' \times \frac{1}{4}''$	Piece of side plate.
9	Piece malleable iron plate $1\frac{3}{4}'' \times 1'' \times$ No. 12 B.W.G.	Probably from roof of holder.
10	Piece malleable iron plate $2\frac{1}{2}'' \times \frac{1}{2}'' \times$ No. 12 B.W.G.	Do. do.
11	Piece malleable iron plate $5\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{1}{4}''$	Piece of side plate of holder.
12	Piece malleable iron plate $4\frac{1}{2}'' \times 2'' \times \frac{1}{4}''$	Do. do.
13	Piece of tape	Marked on plan part of fuse.
14	Piece of tape	Do. do.
15	Piece malleable iron $7'' \times 6\frac{1}{2}'' \times \frac{7}{8}''$, pitted on one side	Part of bracket.
16	Piece malleable iron $4\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{7}{8}''$	Do.
17	Piece cast iron $5\frac{1}{2}'' \times 3'' \times 2\frac{3}{4}''$	Piece of bracket.
18	Piece malleable iron plate $12'' \times 8'' \times \frac{1}{4}''$	Supposed to be part of lute plate.
19	Piece cast iron $4\frac{1}{2}'' \times 1\frac{1}{2}'' \times 1\frac{1}{2}''$	Piece of bracket.
20	Piece cast iron $3'' \times 2\frac{1}{2}'' \times 1\frac{1}{2}''$	Do.
21	Piece malleable iron $4\frac{1}{2}'' \times 2'' \times 1''$	Do.
22	Plate $4\frac{1}{2}'' \times 2'' \times \frac{3}{16}''$	May not be piece of holder.
23	Piece malleable iron $5'' \times 1\frac{1}{2}'' \times$ No. 12 B.W.G.	Roof of holder.
24	Piece malleable iron plate $2'' \times 1\frac{1}{2}'' \times \frac{1}{4}''$	Part of side plate; shows evidence of having passed through roof of bolder.
25	Piece malleable iron $12'' \times 5'' \times$ No. 12 B.W.G.	Part of roof.
26	Piece malleable iron $6'' \times 3'' \times$ No. 12 B.W.G.	Do.
27	Piece malleable iron $5'' \times 1\frac{1}{2}'' \times$ No. 12 B.W.G.	Do.
28	Piece cast iron $7'' \times 6'' \times 1\frac{1}{2}''$	Piece of bracket.
29	Piece of bolt $5'' \times 1\frac{1}{4}''$ with nut	Centre bolt of bracket.
30	Piece cast iron $9'' \times 4'' \times 1\frac{1}{4}''$	Piece of bracket.
31	Piece cast iron $2\frac{1}{2}'' \times 1'' \times \frac{3}{4}''$	Do.
32	Bolt head $\frac{3}{4}''$ diameter	Do.
33	Piece cast iron $3'' \times 2\frac{1}{4}'' \times 1\frac{1}{2}''$	Piece of bracket (pulley).
34	Piece of bolt $16'' \times 1''$	Forming attachment between bracket and chain.
35	Piece of bolt $3\frac{1}{2}'' \times \frac{3}{4}''$ with nut	Piece of bracket.
36	Piece cast iron $4'' \times 2'' \times \frac{7}{8}''$	Do.
37	Piece cast iron $5'' \times 2\frac{1}{2}'' \times 1\frac{1}{4}''$	Do.
38	Piece cast iron $6'' \times 2\frac{3}{4}'' \times \frac{3}{4}''$	Do.
39	Piece cast iron $5'' \times 1\frac{1}{2}'' \times 1\frac{1}{2}''$	Do.
40	Other part of No. 34, 18" long	—
41	Piece cast iron $4'' \times 3'' \times 2\frac{1}{2}''$	Piece of bracket.
42	Piece cast iron $6'' \times 4'' \times 1\frac{1}{4}''$	Do.
43	Piece cast iron $3'' \times 2\frac{1}{2}'' \times 1\frac{1}{4}$	Do.
44	Piece of cast iron $6'' \times 5'' \times 1\frac{1}{4}''$	Do.
45	Piece malleable iron $4'' \times 2\frac{1}{2}'' \times \frac{7}{8}''$ deeply pitted on one side.	Do.
46	Piece cast iron $4\frac{1}{2}'' \times 1'' \times 1'' \times 1\frac{1}{2}'' \times 1''$	Piece of sole plate of bracket.
47	Piece cast iron $7'' \times 2\frac{1}{2}'' \times 1\frac{1}{2}''$ pitted on one side	Piece of bracket (pulley).
48	Two pieces cast iron, one probably not belonging to holder, the other $7'' \times 2\frac{1}{2}'' \times \frac{7}{8}''$.	One piece probably not part of holder, other piece of bracket.
49	Piece malleable iron $8\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{7}{8}''$ deeply pitted on one side.	Piece of bracket.
50	Piece cast iron $4\frac{1}{2}'' \times 2\frac{1}{2}'' \times 1\frac{1}{2}''$	Part of pulley of bracket.
51	Piece cast iron $2\frac{1}{2}'' \times 2\frac{1}{4}'' \times 1\frac{3}{4}''$ pitted on one side	Do. do.
52	Piece cast iron $9'' \times 4\frac{1}{2}'' \times 1\frac{1}{4}''$	Piece of bracket.
53	Piece malleable iron $5'' \times 2\frac{3}{4}'' \times \frac{7}{8}''$ pitted on one side	Do.
54	Broken guide rail bracket	—

No.	—	Remarks.
55	Piece cast iron 8″×2″×1″ - - - -	Part of guide rail bracket.
56	Piece cast iron 9″×2½″×1½″ - - -	Piece of bracket (pulley).
57	Piece malleable iron 3″×1½″×⅜″ - - -	—
58	Piece malleable iron 4″×1½″×⅜″ - - -	—
59	Piece cast iron 3″×2″×1½″ - - - -	Part of pulley of bracket.
60	Bolt head ½″ diameter - - - -	Piece of bracket.
61	Piece of rod iron forming part of chain attachment, pitted deeply.	Supposed to have been carried over the top girder with recoil of chain.
62	Piece malleable iron plate 9″×1½″×No. 12 B.W.G. -	Piece of roof.
63	Piece cast iron 6″×2″×¾″ - - - -	Piece of pulley at top of column.
64	Piece malleable iron 6½″×2″×½″ - - -	Supposed to be piece of channel iron forming lute.
65	Piece of malleable iron 1¼″× 1¼″×⅜″ - -	Found on top of gasholder.
66	Piece cast iron 5″×3½″×½″ - - - -	Part of ornamental casting on front of column.
67	Piece cast iron 5″×2″×⅞″ - - - -	—
68	Small piece plate - - - - -	Top of gasholder.
—	Circular rusty metal with three nipples and caps -	Exploded railway fog signal.
—	Circular brass cap - - - - -	—

No	Description of Holes on top of Gasholder.
1	Bulged and cracked - - - projectile has not passed through plate.
2	Hole 3″×2½″
2A	Bulged not broken.
3	Hole 2″×2″
4	Do. 9″×3″
5	Do. 12″×3″
6	Do. 5″×4″
7	Do. 22″×7″
8	Do. 30″×6″ to 3″
9	Do. 15″×5″
10	Do. 3″×½″
11	Do. 6″×3″
12	Do. 1½″×¾″
13	Do. 3″×¾″
14	Do. 20″×4½″
14A	Bulged, cracked - - - projectile has not passed through plate.
15	Hole 7″×5″
16	Bulged and cracked - - - projectile has not passed through plate.
17	Do. do. - - - Do. do.
18	Hole 3″×¾″
19	Bulged and cracked - - - projectile has not passed through plate.
20	Hole 5″×½″
20A	Bulged only.

APPENDIX B.

Results of Experiments by Admiralty Committee.

Details of Experiments with a mixture of Coal Gas and Air in Water Tanks at Woolwich, with Lithographs. Plates 1 to 5.

Date and Place.	Details of Construction of Tank.	Description of Experiment.	Effects of Explosion.
7th February 1882, Woolwich Arsenal. (1.)	Tank A, 4 ft. × 4 ft. × 6 ft., constructed of wrought-iron plates $\frac{3}{16}$ in. (·1875), bent to form the angles, and riveted together with $\frac{3}{8}$ in. (·375) snap rivets, a single row of rivets at joints. The top was composed of one plate 4 ft. × 4 ft., with man-hole in centre and cast-iron ring for securing lid; the bottom and sides were composed of plates 4 ft. × 2 ft. and 2 ft. × 2 ft. The sides were supported by four 1 in. round iron stays, attached to cast-iron dovetailed brackets, which were riveted to the plates.	The tank was laid on one side with its opening facing the proof butt in the Arsenal. A tube was then passed through a small perforation in the lid, so as to reach the bottom of the tank, by which gas was introduced, a corresponding volume of air being allowed to escape until the proportions in the tank were one volume of coal gas (of high illuminating power) and seven volumes of air. A large disc of stiff paper, attached to a wire, having been placed in the tank before the gas was introduced, and the wire passed through a small hole made in the lid of the tank, the lid was luted down with soft cement; the diaphragm of paper was, when the gas had been passed in, pulled up and down repeatedly to promote the rapid mixture of the air and gas. The string was then pushed into the tank, and the opening in the lid tightly plugged up. An electric fuze, suitably attached to insulated wires and a supporting rod of wood, had been previously passed into the tank through another small opening in the lid; the gas mixture was exploded by means of this fuze.	The top end of the tank, facing the proof butt, was broken through the centre across the man-hole, vertically with the ground; the cast-iron ring for securing the lid was broken into six pieces, which remained partly attached to the plate; the lid was blown to a distance of 17 ft., and stopped by the proof butt. The left angle of the top plate was also broken from top to bottom, and the plate bulged out 4·25 in. The bottom, facing north, was not broken, but bulged out 1·25 in. The side facing west was bulged out at the top edge 24 in., and the side angle of the plate was broken. The side facing east was bulged out at the top edge 12·5 in., and the bottom angle of the centre plate was broken. The upper side was bulged up on one side 21 in., and on the other 13 in.; the plates were broken at both angles from end to end. The side next to the ground was bulged out 1·5 in. Four of the cast-iron brackets for securing the stays to sides were broken; the stays were greatly bent, and one of them broken. A somewhat loud report and a considerable volume of flame were observed.
13th February 1882, Woolwich Arsenal. (2.)	Tank B, 4 ft. × 4 ft. × 2 ft., constructed of wrought-iron plates $\frac{3}{16}$ in. thick; one portion of the top plate was $\frac{5}{32}$ in. thick. The plates were bent to form the angles of the tank, and single riveted with $\frac{3}{8}$ in. rivets. The top was composed of two plates 4 ft. × 2 ft., with man-hole in one corner and cast-iron ring for securing the lid; the bottom and sides were of plates 4 ft. × 2 ft. and 2 ft. × 2 ft.	Do. In this tank was a mixture of large and small coal.	After the explosion the top was found to be bulged out about 8 in., and to be torn across from the man-hole on one side to a distance of 8¼ in., and on the other side to 28½ in. The cast iron ring was broken through at both places. A third small crack about 2 in. long, with a third fracture of the ring, was also developed on the top. The lid was sent about 60 ft. into the air by the explosion in an almost vertical line. The coal which was in the tank was not affected by the explosion.
15th February 1882, Woolwich Arsenal. (3.)	Tank C, 6 ft. × 4 ft. × 4 ft. The construction of this tank was the same as that of tank .	Do. This tank contained about 4 lb. or 5 lb. of coal dust on the bottom, and 1 lb. suspended in a thin paper bag two feet from the top.	By the explosion one side was opened out along its entire length from top to bottom, being torn away at one corner; the bottom plate from this side, 2 ft. × 4 ft., also parted from the bottom along the line of rivets 2 ft. 11 in., leaving only 13 in. of the plate attached to the bottom; it also parted from the other plates of this side. The remainder of the plates on this side stood up 2 ft. 8 in. from the original position.

Date and Place.	Details of Construction of Tank.	Description of Experiment.	Effects of Explosion.
15th February 1882. (3) (*continued.*)			The top, bottom, and remaining sides were more or less bulged The cast-iron ring round the manhole was cracked in one place but not broken through, and the cover remained in position. 1 side bulged 10 inches. 1 ,, 5 ,, 1 ,, about 6 ,, Bottom ,, 1 ,, Top ,, 1 ,, Five of the cast-iron sockets were broken, and two stays were drawn completely out of the dovetails and bent. Two stays remained attached by one end. The explosion was accompanied by a large body of yellow flame of some duration, and a considerable amount of smoke was produced. The card-board disc used for stirring the gas mixture and which remained in the tank was not discoloured by the explosion, and the thin paper forming the bag which contained coal-dust only exhibited faint symptoms of discoloration by the heat in two or three places. The tank was thrown on its side by the explosion, and the lid was not displaced. In falling over the tank became partly immersed in an adjoining pond.
15th February 1882, Woolwich Arsenal. (4)	Tank D, 4 ft. × 4 ft. × 2 ft. The construction of this tank was the same as that of tank B	The tank was prepared as in 1, 2, and 3, and placed on its bottom with the man-hole in the top-plate. The bottom was covered with lumps of a bright caking coal.	The top was bulged up 20 in., and broken along one angle to a length of 34 in., not along the rivets, the ring for securing the lid was broken in ten pieces, the fracture passing across the man-hole, tearing the plate to a distance of 9 inches on the opposite. One side of the tank was bulged out 1 in., and was broken along the top angle 21 in., across a joint running 8 in. into the top plate. 1 side bulged out $\frac{5}{8}$ inch. 1 ,, ,, $\frac{1}{2}$,, 1 ,, ,, $1\frac{1}{4}$,, Bottom ,, 1 ,, The coal in the bottom of the tank was found not to have been in the least affected by the explosion. The card-board disc used for mixing the gas and air (and which remained in the tank) was not discoloured. When the explosion took place there was a flash of flame, the tank bounded sidewards and fell over the bank of a pond 5 feet distant. The lid was projected in a slanting direction to a height of at least 60 feet, and fell upon the top of the adjoining proof butt, about 50 yards distant in a horizontal direction.

APPENDIX C.

GAS delivered per hour from TRADESTON GASWORKS from 6 p.m. to midnight on the following Saturdays viz.:—

—	6 to 7 o'clock.	7 to 8 o'clock	8 to 9 o'clock.	9 to 10 o'clock	10 to 11 o'clock	11 to 12 o'clock.
			Cubic feet.			
1882.						
December 2nd -	330,000	325,000	305,000	298,000	263,000	174,000
" 9th -	317,000	307,000	300,000	284,000	257,000	180.000
" 16th -	329,000	296,000	270,000	281,000	289,000	212,000
" 23rd -	305,000	321,000	292,000	303,000	272,000	189,000
" 30th -	285,000	289,000	279,000	280,000	280,000	236,000
1883.						
January 6th -	313,000	303,000	303,000	293,000	267,000	198,000
" 13th -	286,000	288,000	291,000	277,000	262,000	152,000
" 20th -	266,000	267,000	262,000	246,000	*618,000*	122,000

N.B.—The large consumption of gas during the hour 10 to 11 on 20th January was due to the escape resulting from the destruction of the holder.

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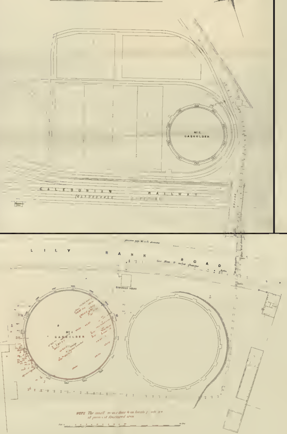
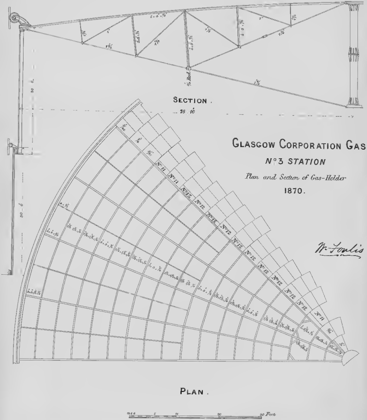
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.

Plate No. 1.

GLASGOW CORPORATION GAS.

Explosion at Gasholder No. 1 Tradeston Station
Plan showing positions of fractures in roof of Gasholder and of pieces of fractured iron found lying about.


No. 2 GASHOLDER
CALEDONIAN RAILWAY
LILY BANK ROAD
GOVERNOR HOUSE
No. 1 GASHOLDER
NOTE The small crosses thus + in brown [illegible] of pieces of fractured iron



GLASGOW CORPORATION GAS

No 3 STATION

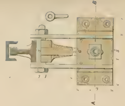
Plan and Section of Gas-Holder

1870.

W. Foulis

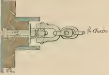
[illegible] Lith 22 Bedford S. Covent Garden 5557

Plate No 3

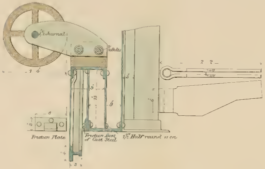


PLAN OF BRACKETS
and attachment to cap

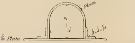
CROSS SECTION THRO' A B



CROSS SECTION OF BRACKET



SIDE ELEVATION OF BRACKET AND SECTION
THROUGH CUP



SCALE OF FEET

Danielsson & Co Lith 22 Bedford S. Covent Garden

PLATE Nº 4

GLASGOW CORPORATION GAS

EXPLOSION AT TRADESTON

[illegible] BOTTOM OF GASHOLDER SHEWING BROKEN PIECES OF IRON
FEBY 1883

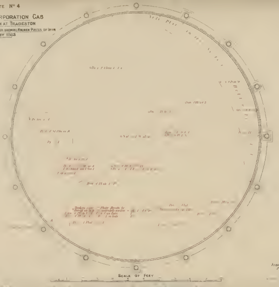


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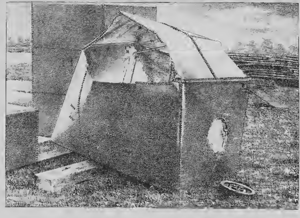
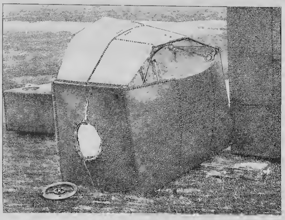
PLATE No 5.





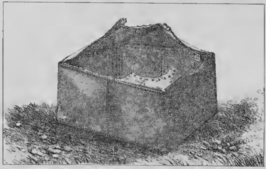


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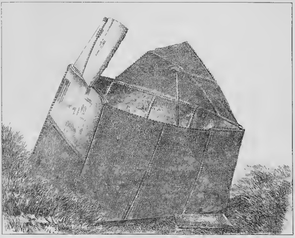
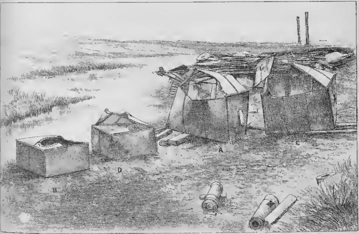
PLATE No 6.





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